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 thirty passenger motor vehicles for replacement only, $4,397,876,000, to remain available until expended.

Science
Office of Science

Overview

Appropriation Summary by Program

(dollars in thousands)

	FY 2006 Current Appropriation	FY 2007 Request	FY 2007 CR	FY 2008 Request
Science				
Basic Energy Sciences	1,110,148	1,420,980	1,197,084	1,498,497
Advanced Scientific Computing Research	228,382	318,654	234,514	340,198
Biological and Environmental Research	564,077	510,263	461,685	531,897
High Energy Physics	698,238	775,099	731,786	782,238
Nuclear Physics	357,756	454,060	396,166	471,319
Fusion Energy Sciences	280,683	318,950	305,151	427,850
Science Laboratories Infrastructure	41,684	50,888	41,986	78,956
Science Program Direction	159,118	170,877	161,469	184,934
Workforce Development for Teachers and Scientists	7,120	10,952	7,128	11,000
Small Business Innovation Research/Technology Transfer	116,813[a]	—	—	—
Safeguards and Security	73,630	76,592	73,636	76,592
Subtotal, Science	3,637,649	4,107,315	3,610,605	4,403,481
Less security charge for reimbursable work	-5,605	-5,605	-5,605	-5,605
Total, Science	3,632,044[b]	4,101,710	3,605,000	4,397,876
FTEs	949	1,014	989	1,058

Preface

As part of the second year of the President's American Competitiveness Initiative, the Office of Science (SC) request for Fiscal Year (FY) 2008 is $4,397,876,000; an increase of $296,166,000, or 7.2%, over the FY 2007 request. The request funds investments in basic research that are important both to the future economic competitiveness of the United States and to the success of Department of Energy (DOE) missions in national security and energy security; advancing the frontiers of knowledge in the physical sciences and areas of biological, environmental, and computational sciences and providing world-class research facilities for the Nation's science enterprise.

---

[a] Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) includes $81,160,000 reprogrammed within Science plus $35,653,000 transferred from other DOE organizations.
[b] Total is reduced by $36,327,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006

SC provides support for the basic research and scientific and technological capabilities that underpin the Department's technically complex missions. Part of this support is in the form of large-scale scientific user facilities. The suite of forefront facilities includes the world's highest energy proton accelerator (Fermi National Accelerator Laboratory's Tevatron) and the world's forefront neutron scattering facility (the Spallation Neutron Source at Oak Ridge National Laboratory), which began operations in 2006. SC facilities represent a continuum of unique capabilities that meet the needs of a diverse set of over 20,000 researchers each year. For example, the National Synchrotron Light Source (NSLS) began ultraviolet operations in 1982 and initially primarily enabled physical science research. However, through the 1990's the numbers of researchers from the life sciences rapidly grew as the characteristics of this facility better suited the needs of researchers who study protein structure. Today, the NSLS is playing a major role in the Protein Structure Initiative, a national effort to find the three-dimensional shapes of a wide range of proteins, while also providing a suite of beamlines to the soon to be available Center for Functional Nanomaterials and a host of other research efforts. The Department's five Nanoscale Science Research Centers and the computational resources at the National Energy Research Scientific Computing Center (NERSC) and Leadership Computing Facilities offer technological capabilities to the research community that are unmatched anywhere in the world.

The centerpiece of the American Competitiveness Initiative is President Bush's strong commitment to double investments over 10 years in key Federal agencies that support basic research programs in the physical sciences and engineering: SC, the National Science Foundation, and the Department of Commerce's National Institute for Standards and Technology core activities. While the American Competitiveness Initiative encompasses all SC funding, SC also supports other Presidential initiatives and priorities, such as the Advanced Energy Initiative, the Hydrogen Fuel Initiative, the National Nanotechnology Initiative, Networking and Information Technology Research and Development, the Climate Change Science Program, and ITER, an international nuclear fusion project.

Within the Science appropriation, SC has ten programs: Basic Energy Sciences (BES), Advanced Scientific Computing Research (ASCR), Biological and Environmental Research (BER), High Energy Physics (HEP), Nuclear Physics (NP), Fusion Energy Sciences (FES), Science Laboratories Infrastructure (SLI), Science Program Direction (SCPD), Workforce Development for Teachers and Scientists (WDTS), and Safeguards and Security (S&S).

Mission

SC's mission is to deliver the remarkable discoveries and scientific tools that transform our understanding of energy and matter and advance the national, economic, and energy security of the United States.

Benefits

SC supports basic research and technological capabilities that drive scientific discovery and innovation in the U.S. and underpin the Department's missions in energy, the environment, and national security. Important contributions to meeting DOE's applied mission needs are expected through developments in materials and chemical sciences, especially at the nanoscale, such as strong, tough, ductile, lightweight materials with low failure rates that will improve the fuel efficiency and innovative systems for harvesting light and storing energy that will dramatically improve solar energy conversion. The science, technology, and knowledge base developed from the Genomics: GTL program on understanding and harnessing the capabilities of microbial and plant systems could lead to cost-effective, renewable energy production, greater energy security, clean-up of legacy wastes, and tools for modifying concentrations of atmospheric CO_2 or for evaluating environmental impacts.

Computational modeling and simulation can improve our understanding of, and sometimes predict the behavior of complex systems and develop solutions to research problems that are insoluble by traditional or experimental approaches, too hazardous to study in the laboratory, or too time-consuming or expensive to solve by traditional means, including challenges such as understanding the fundamental processes associated with fluid flow and turbulence, chemical reactivity, climate modeling and prediction, molecular structure and processes in living cells, subsurface biogeochemistry, and astrophysics. Fusion, a fundamentally new source of energy under development, has the potential to provide a significant fraction of the world's energy by the end of the century. The international ITER project is a bold next step in fusion research, designed to produce, control, and sustain a burning plasma. Through investments in high-energy physics and nuclear physics, SC has historically provided the Nation with fundamental knowledge about the laws of nature as they apply to the basic constituents of matter and the forces between them. These investments in high energy and nuclear physics have enabled the U.S. to maintain a leading role in the development of technologies in areas such as nuclear energy, materials, semiconductors, nuclear medicine, and national security, and technologies such as the accelerator technologies leading to high-power x-ray light sources and advanced imaging techniques have been important to other fields of science.

Strategic Themes and Goals and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. Science supports the following goals:

Strategic Theme 3, Scientific Discovery and Innovation: Strengthening U.S. scientific discovery, economic competitiveness, and improving quality of life through innovations in science and technology.

Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

The programs funded by the Science appropriation have the following six GPRA Unit Program Goals which contribute to the Strategic Goals in the "goal cascade":

GPRA Unit Program Goal 3.1/2.50.00: Advance the Basic Science for Energy Independence—Provide the scientific knowledge and tools to achieve energy independence, securing U.S. leadership and essential breakthroughs in basic energy sciences.

GPRA Unit Program Goal 3.1/2.51.00: Deliver Computing for Accelerated Progress in Science—Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

GPRA Unit Program Goal 3.1/2.48.00: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally change the nature of medical care to improve human health.

GPRA Unit Program Goal 3.1/2.46.00: Explore the Fundamental Interactions of Energy, Matter, Time, and Space—Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe, search for possible new dimensions of space, and investigate the nature of time itself.

GPRA Unit Program Goal 3.1/2.47.00: Explore Nuclear Matter, from Quarks to Stars—Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks, and gluons; to the stable elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability and possess radically different properties from known matter.

GPRA Unit Program Goal 3.1/2.49.00: Bring the Power of the Stars to Earth—Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels our sun.

Contribution to Strategic Goals

Six of the programs within the Science appropriation directly contribute to Strategic Goals 3.1 and 3.2 as follows:

Basic Energy Sciences (BES) contributes to Strategic Goals 3.1 and 3.2 by producing advances in the core disciplines of basic energy sciences—materials sciences and engineering, chemistry, geosciences, and biosciences. The scientific discoveries at the frontiers of these disciplines impact energy resources, production, conservation, efficiency, and the mitigation of adverse impacts of energy production and use—discoveries that will help accelerate progress toward long-term energy independence, economic growth, and a sustainable environment. BES also provides the Nation's researchers with world-class research facilities, including reactor and accelerator-based neutron sources, light sources including the X-ray free electron laser currently under construction, and electron beam micro-characterization centers. These facilities provide important capabilities for imaging and characterizing materials of all kinds from metals, alloys, and ceramics to semiconductors and fragile biological samples; and for studying the chemical transformation of materials. Construction of the Spallation Neutron Source was completed in FY 2006 and will enter its second full year of operation in FY 2008. Major items of equipment are supported in FY 2008 for the fabrication of approximately nine to ten additional instruments for the SNS. All five Nanoscale Science Research Centers will be operational in FY 2008—the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory, the Molecular Foundry at Lawrence Berkeley National Laboratory, the Center for Nanoscale Materials at Argonne National Laboratory, the Center for Integrated Nanotechnologies at Sandia National Laboratories and Los Alamos National Laboratory, and the Center for Functional Nanomaterials at Brookhaven National Laboratory. The Linac Coherent Light Source (LCLS) at SLAC will continue construction at the planned level, including partial support for the SLAC linac. The Transmission Electron Aberration Corrected Microscope project continues as a major item of equipment. Support is provided for research and development (R&D) and project engineering and design (PED) activities for the National Synchrotron Light Source–II (NSLS–II) to enable the study of material properties and functions, particularly materials at the nanoscale, at a level of detail and precision never before possible. BES will increase support for basic research for the President's Hydrogen Fuel Initiative solar energy utilization and electric-energy storage. BES also continues ongoing Scientific Discovery through Advanced Computing (SciDAC) efforts.

Advanced Scientific Computing Research (ASCR) contributes to Strategic Goals 3.1 and 3.2 by advancing fundamental mathematics and computer science research that enables simulation and prediction of complex physical, chemical, and biological systems; providing the advanced computational capabilities needed by researchers to take advantage of that understanding; and delivering the fundamental networking research and facilities that link scientists across the nation to the computing and experimental facilities. ASCR has been a leader in the computational sciences for several decades and supports research in applied mathematics, computer science, specialized algorithms, and scientific software tools that enable scientific discovery essential for research program across SC, as well as other elements of the Department. By the end of FY 2008, the Leadership Computing Facility at Argonne National Laboratory will expand to 250–500 teraflops of high performance computing capability with low electrical power needs to accelerate scientific understanding in areas that include materials science, biology, and advanced designs of nuclear reactors. The Leadership Computing Facility at Oak Ridge National Laboratory will acquire a 1 petaflop (quadrillions of processes per second) Cray Baker system in late FY 2008 to enable further scientific advancements. Delivery of the next generation of high performance resources at the National Energy Research Scientific Computing Center (NERSC) is scheduled for early FY 2007. This NERSC-5 system is expected to provide 100–150 teraflops of peak computing capacity. Expanded efforts in Applied Mathematics will support critical long term mathematical research issues relevant to petascale science, multiscale mathematics, and optimized control and risk analysis in complex systems. Expanded efforts in Computer Science will enable scientific applications to take full advantage of high-end computing systems at the Leadership Computing Facilities.

Biological and Environmental Research (BER) contributes to Strategic Goals 3.1 and 3.2 by advancing energy-related biological and environmental research in genomics and our understanding of complete biological systems, such as microbes that produce ethanol from cellulose; by developing models to predict climate over decades to centuries; by developing science-based methods for cleaning up environmental contaminants and for long-term stewardship of the sites; by providing regulators with a stronger scientific basis for developing future radiation protection standards; and by conducting limited research in medical imaging, radiotracers, and development of an artificial retina. Discoveries at these scientific frontiers may bring transformational and unconventional solutions to some of our most pressing and expensive problems in energy and the environment. BER continues the Genomics: GTL program as its top priority, employing a systems approach to biology at the interface of the biological, physical, and computational sciences for DOE's energy security and environmental mission needs. As part of the GTL program, BER will continue to support the development of two Bioenergy Research Centers to be selected and initiated in FY 2007 and will add and support a third Center in FY 2008. All three centers will conduct comprehensive, multidisciplinary research programs focused on microbes and plants to drive scientific breakthroughs that will aid in the development of cost-effective biofuels and bioenergy production. The sequencing capacity of the Production Genomics Facility will increase in FY 2008 to support the growing demand and needs of the DOE research mission. Structural Biology infrastructure and innovative research on the biological effects of low dose radiation needed for future radiation protection standards will be sustained. BER continues as a partner in the interagency Climate Change Science Program focusing on understanding the principal uncertainties of the causes and effects of climate change, including abrupt climate change, understanding the global carbon cycle, developing predictive models for climate change over decades to centuries, and supporting basic research for biological sequestration of carbon. Basic research in Environmental Remediation continues to support fundamental research at the interfaces of biology, chemistry, geology, hydrology, and physics for solutions to environmental contamination challenges, including research for the development of two new field research sites providing new opportunities to validate laboratory findings under field conditions. Support for the Environmental Molecular Sciences Laboratory continues to provide integrated experimental and technological resources to the scientific community and support for instrumentation and operation of the three Atmospheric Radiation Measurement facilities continues.

High Energy Physics (HEP) contributes to Strategic Goals 3.1 and 3.2 by advancing understanding of the basic constituents of matter, deeper symmetries in the laws of nature at high energies, and mysterious phenomena that are commonplace in the universe, such as dark energy and dark matter. Research at these frontiers of science may uncover new particles, forces, or undiscovered dimensions of space and time; explain how matter came to have mass; and reveal the underlying nature of the universe. HEP supports particle accelerators and very sensitive detectors to study fundamental particle interactions at the highest possible energies as well as non-accelerator studies of cosmic particles using experiments conducted deep underground, on mountains, or in space. HEP places a high priority on maximizing scientific data derived from the three major HEP user facilities: the Tevatron Collider and Neutrinos at the Main Injector (NuMI) beam line at Fermilab, and the B-factory at SLAC. HEP will continue to lead the world with these forefront user facilities at Fermilab and SLAC in FY 2008, but these facilities will complete their scientific missions by the end of the decade. Thus the longer-term HEP program supported by this request begins to develop new cutting-edge facilities in targeted areas (such as neutrino physics) that will establish U.S. leadership in these areas in the next decade, when the centerpiece of the world HEP program will reside at CERN (the European Organization for Nuclear Research). HEP continues to support software and computing resources for U.S. researchers participating in the Large Hadron Collider (LHC) program at the CERN laboratory as well as pre-operations and maintenance of the U.S.-built systems that are part of the LHC detectors. HEP maintains support for International Linear Collider (ILC) R&D to support a U.S. role in a comprehensive and coordinated international R&D program, should the ILC be built. The NuMI Off-axis Neutrino Appearance (NOνA) Detector, which was originally proposed as a line item construction project in FY 2007 under the generic name of Electron Neutrino Appearance (EνA) Detector, continues in FY 2008. In addition, new Major Items of Equipment beginning fabrication in FY 2008 are the Dark Energy Survey project, a small experiment to measure neutrino interactions with ordinary matter in the NuMI beam (Main Injector Experiment ν–A [MINERνA]), and U.S. contributions to the Japanese Tokai-to-Kamioka (T2K) neutrino oscillation experiment. Activities to improve the intensity of the proton beam for the ongoing neutrino program at Fermilab continue and HEP supports further R&D on superconductive radiofrequency (RF) technologies in FY 2008.

Nuclear Physics (NP) contributes to Strategic Goals 3.1 and 3.2 by supporting peer-reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, and, in particular, to investigate the fundamental forces which hold the nucleus together and determine the detailed structure and behavior of the atomic nuclei. NP builds and supports world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda of fundamental nuclear physics and training a workforce relevant to the Department's missions for nuclear-related national security, energy, and environmental quality. NP also supports an effort in nuclear data that collects, evaluates, and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies, such as the design of next generation reactors. World-leading efforts on studies of hot, dense nuclear matter and the origin of the proton spin with beams at the Relativistic Heavy Ion Collider (RHIC) will continue, including implementation of required instrumentation to realize scientific goals. Construction of the Electron Beam Ion Source (EBIS) continues together with the National Aeronautics and Space Administration (NASA) to provide RHIC with more cost-effective, reliable operations and new research capabilities. In addition to RHIC efforts, the studies of hot, dense nuclear matter include NP contributions to enhance heavy ion capabilities of existing LHC experiments and the accompanying research program at universities and laboratories. Operations of the Continuous Electron Beam Accelerator Facility (CEBAF) are supported to provide high-energy electron beams to investigate a unique property called "confinement" that binds together the fundamental constituents of protons and neutrons, particles called quarks and gluons. The accelerator provides beams simultaneously to all three experimental halls to better understand the structure of the nucleon. Support is provided to complete project engineering and design of the 12 GeV Upgrade to CEBAF in FY 2008 as well as continue upgrade-related R&D activities. NP also continues efforts in nuclear structure/astrophysics, fundamental interactions, and neutrinos. Efforts at the Argonne Tandem Linac Accelerator System (ATLAS) and the Holifield Radioactive Ion Beam Facility (HRIBF) will be supported to focus on investigating new regions of nuclear structure, studying interactions in nuclear matter like those occurring in neutron stars, and determining the reactions that created the nuclei of the chemical elements inside stars and supernovae. R&D on rare isotope beam development, relevant for next-generation facilities in nuclear structure and astrophysics continues in FY 2008. Fabrication of the GRETINA gamma-ray tracking array, which will revolutionize gamma ray detection technology is supported in FY 2008 and will offer dramatically improved capabilities to study the structure of nuclei at ATLAS and HRIBF. The Fundamental Neutron Physics Beamline (FNPB) and neutron Electric Dipole Moment experiment under fabrication at the SNS continues and, when completed, will deliver record peak currents of cold neutrons and ultracold neutrons for studies of the fundamental properties of neutrons and search for new physics beyond the Standard Model. R&D and design activities are supported for neutrino-less Double Beta Decay experiments and funds are provided to initiate the fabrication of one of the candidate neutrino-less Double Beta Decay experiments, the Cryogenic Underground Observatory for Rare Events (CUORE), which will measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle.

Fusion Energy Sciences (FES) contributes to Strategic Goals 3.1 and 3.2 by advancing the theoretical and experimental understanding of plasma and fusion science through its domestic research and development activities and a close collaboration with international partners on specialized facilities abroad, including ITER. In addition to supporting fundamental research into the nature of fusion plasmas, FES supports the operation of a set of unique and diversified experimental facilities. These facilities provide scientists with the means to test and extend our theoretical understanding and computer models—leading ultimately to improved predictive capabilities for fusion science. Advances in plasma physics and associated technologies will bring the U.S. closer to making fusion energy a part of the Nation’s energy solution. ITER, an experiment to study and demonstrate the scientific and technical feasibility of fusion power, is a multi-billion dollar international research project that will, if successful, move towards developing fusion’s potential as a commercially viable, clean, long-term source of energy near the middle of the century. FES continues to lead the U.S. Contributions to the ITER project and places increased emphasis on its national burning plasma program. The U.S. Contributions to the ITER project provides for the U.S. “in-kind” equipment contributions, U.S. personnel to work at the ITER site, and cash for the U.S. share of common expenses such as infrastructure, hardware assembly, installation, and contingency. The funding for ITER increases in FY 2008 to provide for procurements for fabrication of significant hardware components. Experimental research on tokamaks is continued in FY 2008, with continued emphasis on physics issues of interest to the ITER project. The DIII-D tokamak at General Atomics (a private company), will operate for 15 weeks in FY 2008 to conduct research relevant to burning plasma issues and topics of interest to the ITER project in addition to maintaining the broad scientific scope of the program. Operations at Alcator C-Mod at the Massachusetts Institute of Technology will be maintained at 15 weeks and operations at the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory (PPPL) will remain at 12 weeks. Fabrication of the major components of the National Compact Stellarator Experiment (NCSX) at PPPL continues and assembly of the entire device will be completed in FY 2009. FES will issue a joint solicitation in FY 2008, with the National Nuclear Security Administration (NNSA), focused on academic research in high energy density laboratory plasmas (HEDLP), which supports the Department’s programmatic goals in inertial confinement fusion science.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Discovery and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.50.00, Advance the Basic Science for Energy Independence (BES)	1,110,148	1,420,980	1,498,497
GPRA Unit Program Goal 3.1/2.51.00, Deliver Computing for Accelerated Progress in Science (ASCR)	228,382	318,654	340,198
GPRA Unit Program Goal 3.1/2.48.00, Harness the Power of Our Living World (BER)	564,077	510,263	531,897
GPRA Unit Program Goal 3.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time, and Space (HEP)	698,238	775,099	782,238
GPRA Unit Program Goal 3.1/2.47.00, Explore Nuclear Matter, from Quarks to Stars (NP)	357,756	454,060	471,319
GPRA Unit Program Goal 3.1/2.49.00, Bring the Power of the Stars to Earth (FES)	280,683	318,950	427,850
Subtotal, Strategic Goals 3.1, Scientific Discovery and 3.2, Foundations of Science	3,239,284	3,798,006	4,051,999
All Other			
Science Laboratories Infrastructure	41,684	50,888	78,956
Program Direction	159,118	170,877	184,934
Workforce Development for Teachers and Scientists	7,120	10,952	11,000
Small Business Innovation Research/Technology Transfer	116,813	—	—
Safeguards and Security	73,630	76,592	76,592
Total, All Other	398,365	309,309	351,482
Total, Strategic Goals 3.1 and 3.2 (Science)	3,637,649	4,107,315	4,403,481

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews.

In the FY 2005 PART review, OMB assessed six SC programs: ASCR, BES, BER, FES, HEP, and NP. Program scores ranged from 82–93%. Three programs—BES, BER, and NP—were assessed "Effective." Three programs—ASCR, FES, and HEP—were assessed "Moderately Effective." In general the FY 2005 assessment found that these SC Programs have developed a limited number of adequate performance measures. These measures have been incorporated into this Budget Request, grant solicitations, and the performance plans of senior managers. As appropriate, they are being incorporated into the performance-based contracts of management and operating (M&O) contractors.

SC has taken steps to enhance public understanding of our complex scientific performance measures by developing a PART website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report. Roadmaps with detailed information on tracking progress toward the long-term measures have been developed with the Scientific Advisory Committees and links to these reports are provided on SC's PART website. The Scientific Advisory Committees are reviewing progress toward those measures vis-à-vis the roadmaps every three to five years. The first reviews are being conducted during FY 2006 and early FY 2007. Links to the results of these reviews will be provided on SC's PART website as they become available.

OMB did not complete a PART for any SC Programs for the FY 2008 Budget, but has provided SC with recommendations to further improve performance. The improvement plan action items for the current fiscal year may be found at http://ExpectMore.gov (search by program name).

SC has incorporated this feedback from OMB into the FY 2008 Budget Request decision process, and will continue to take the necessary steps to improve performance.

Indirect Costs and Other Items of Interest

Institutional General Plant Projects

Institutional General Plant Projects (IGPPs) are miscellaneous construction projects that are each less than $5,000,000 in TEC and are of a general nature (cannot be allocated to a specific program). IGPPs support multi-programmatic and/or inter-disciplinary programs and are funded through site overhead. Examples of acceptable IGPPs include site-wide maintenance facilities and utilities, such as roads and grounds outside the plant fences or a telephone switch that serves the entire facility.

Examples of current year projects are:

- East Campus Parking Expansion design and construction at Oak Ridge National Laboratory. This project, scheduled for completion in FY 2006, will provide expanded parking capacity for the recently completed Third Party Buildings, Joint Institute for Computational Science/Oak Ridge Center for Advanced Studies, and Research Support Center, as well as the Multiprogram Research Facility. TEC: $3,500,000.
- 5000 Area Utility System Upgrades. This project will provide upgraded utility services for the Oak Ridge National Laboratory East Campus area to support expanded ORNL capability. TEC: $475,000.
- Campus Public Safety Camera System. This project will install video cameras on the exterior of all buildings on the Pacific Northwest National Laboratory campus to allow for monitoring, recording, assessment, and responding to events. Additionally, free standing emergency call stations will be installed to allow staff to immediately seek assistance or report events should the need arise. TEC: $2,326,070.

The following displays IGPP funding by site:

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Oak Ridge National Laboratory	10,000	16,000	16,000
Pacific Northwest National Laboratory	2,000	5,000	5,000
Argonne National Laboratory	—	—	2,000
Total, IGPP	12,000	21,000	23,000

Facilities Maintenance and Repair

The Department's facilities maintenance and repair activities are tied to its programmatic missions, goals, and objectives. Facilities Maintenance and Repair activities funded by the Office of Science or at SC laboratories are displayed in the following tables. SC has set maintenance targets for each of its laboratories to achieve overall facilities maintenance and repair levels consistent with the National Academy of Science recommendation of 2%–4% of replacement plant value for the SC laboratory complex.

Indirect-Funded Maintenance and Repair

Facilities maintenance and repair activities funded indirectly through overhead charges at SC laboratories are displayed below. Since this funding is allocated to all work done at each laboratory, these activities are paid for using funds from SC and other DOE organizations, as well other Federal agencies and other entities doing work at SC laboratories. Maintenance reported to SC for non-SC laboratories is also shown.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Ames Laboratory	1,123	963	997
Argonne National Laboratory	27,386	28,323	28,974
Brookhaven National Laboratory	27,019	24,248	26,844
Fermi National Accelerator Laboratory	9,047	8,166	8,330
Lawrence Berkeley National Laboratory	16,920	13,000	15,904
Lawrence Livermore National Laboratory	2,760	2,850	2,887
Oak Ridge Institute for Science and Education	815	394	393
Oak Ridge National Laboratory	26,907	24,823	25,568
Oak Ridge National Laboratory facilities at Y-12	844	750	750
Office of Scientific and Technical Information	350	464	477
Pacific Northwest National Laboratory	1,865	1,800	1,631
Princeton Physics Plasma Laboratory	5,177	5,089	5,499
Sandia National Laboratory	1,946	1,999	2,045
Stanford Linear Accelerator Center	8,002	7,092	7,234
Thomas Jefferson National Accelerator Facility	2,811	2,622	2,674
Total, Indirect-Funded Maintenance and Repair	132,972	122,583	130,207

Direct-Funded Maintenance and Repair

Generally, facilities maintenance and repair expenses are funded through an indirect overhead charge. In some cases, however, a laboratory may charge maintenance directly to a specific program. An example of this might be if the maintenance were performed in a building used only by a single program. These direct-funded charges are nonetheless in the nature of indirect charges, and are not directly budgeted. The maintenance work for the Oak Ridge Office is direct funded and direct budgeted by the Science Laboratories Infrastructure program. A portion of the direct-funded maintenance and repair expenses reflects charges to non-SC programs performing work at SC laboratories.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Brookhaven National Laboratory	2,009	2,337	2,384
Fermilab National Accelerator Facility	3,235	3,249	3,313
Notre Dame Radiation Laboratory	153	150	154
Oak Ridge Institute for Science and Education	54	—	—
Oak Ridge National Laboratory	21,483	17,542	18,068
Oak Ridge National Laboratory facilities at Y-12	75	75	75
Oak Ridge Office	1,891	2,019	2,065
Stanford Linear Accelerator Center	1,322	1,373	1,400
Thomas Jefferson National Accelerator Facility	50	51	52
Total, Direct-Funded Maintenance and Repair	30,272	26,796	27,511

Deferred Maintenance Backlog Reduction

SC is increasing focus on reducing the backlog of deferred maintenance at its laboratories as part of the Federal Real Property Initiative within the President's Management Agenda. The deferred maintenance backlog at the end of FY 2006 is estimated to be $225,000,000. The Department's goals for asset condition are based on the mission dependency of the asset. For example, the asset condition index target for mission critical facilities is 0.95 or above, where the index is computed as 1.0 minus the ratio of deferred maintenance to replacement plant value. To reduce the deferred maintenance backlog such that SC achieves the goals, SC sets targets for each of its laboratories for activities specifically focused on reduction of the backlog that exceeds Departmental goals. The overall target for deferred maintenance reduction funding is $36,000,000 in FY 2008, an increase of $16,200,000 over the planned level in the FY 2007 request. Deferred maintenance activities are primarily funded by the laboratories as overhead, charged to all uses of the laboratory facilities. These deferred maintenance estimates are in addition to funding of day-to-day maintenance and repair amounts shown in the tables above. In order to assure that new maintenance requirements are not added to the backlog, SC has set targets for our laboratories that, overall, exceed 2% of the SC laboratory complex replacement plant value, commensurate with the industry standard funding level recommended by the National Academy of Sciences of 2–4% of the replacement plant value. The tables below show the targets planned for funding of deferred maintenance backlog reduction.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Argonne National Laboratory	—	2,574	1,983
Brookhaven National Laboratory	—	5,940	7,163
Fermi National Accelerator Laboratory	—	1,980	4,328
Lawrence Berkeley National Laboratory	—	2,178	6,069
Oak Ridge National Laboratory	—	5,544	14,400
Princeton Physics Plasma Laboratory	—	396	465
Stanford Linear Accelerator Center	—	792	686
Thomas Jefferson National Accelerator Facility	—	396	906
Total, Deferred Maintenance Backlog Reduction	—	19,800	36,000

SC Funding for Selected Administration Priorities

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
American Competitiveness Initiative	3,632,044	4,101,710	4,397,876
Advanced Energy Initiative	393,029	535,153	713,137
Hydrogen Fuel Initiative	32,500	50,000	59,500
Climate Change Science Program	130,461	126,187	129,585
Networking and Information Technology Research and Development	247,174	344,672	369,782
National Nanotechnology Initiative	204,893	256,914	285,586
ITER (TPC)	19,315	60,000	160,000

Science
Office of Science
Funding by Site by Program

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Ames Laboratory			
Basic Energy Sciences	21,300	20,857	20,963
Advanced Scientific Computing Research	1,450	562	562
Science Laboratories Infrastructure	150	—	—
Workforce Development for Teachers and Scientists	65	227	245
Safeguards and Security	607	570	670
Total, Ames Laboratory	23,572	22,216	22,440
Ames Site Office			
Science Program Direction	492	520	555
Argonne National Laboratory			
Basic Energy Sciences	173,641	190,810	200,250
Advanced Scientific Computing Research	13,956	28,174	33,570
Biological and Environmental Research	27,312	27,713	24,339
High Energy Physics	11,235	9,748	10,321
Nuclear Physics	20,900	23,682	25,400
Fusion Energy Sciences	990	960	1,000
Science Laboratories Infrastructure	1,246	3,500	6,469
Workforce Development for Teachers and Scientists	1,304	2,056	1,430
Safeguards and Security	8,570	8,462	8,462
Total, Argonne National Laboratory	259,154	295,105	311,241
Argonne Site Office			
Science Program Direction	3,680	3,813	4,125
Berkeley Site Office			
Science Program Direction	3,689	4,241	4,394

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Brookhaven National Laboratory			
Basic Energy Sciences	104,891	133,783	156,906
Advanced Scientific Computing Research	1,037	—	—
Biological and Environmental Research	20,935	18,074	16,735
High Energy Physics	38,894	30,193	31,962
Nuclear Physics	147,211	183,255	184,159
Science Laboratories Infrastructure	4,996	5,297	8,850
Workforce Development for Teachers and Scientists	682	1,013	739
Safeguards and Security	11,229	10,967	10,967
Total, Brookhaven National Laboratory	329,875	382,582	410,318
Brookhaven Site Office			
Science Program Direction	3,538	3,643	4,234
Chicago Office			
Basic Energy Sciences	164,847	130,351	137,149
Advanced Scientific Computing Research	41,421	18,164	19,664
Biological and Environmental Research	250,578	75,868	70,009
High Energy Physics	122,773	120,152	126,574
Nuclear Physics	59,664	61,664	63,658
Fusion Energy Sciences	137,000	129,817	138,417
Science Laboratories Infrastructure	1,228	1,520	1,520
Science Program Direction	24,707	26,162	26,060
Safeguards and Security	2,536	3,400	3,400
SBIR/STTR	116,813	—	—
Total, Chicago Office	921,567	567,098	586,451

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		
Fermi National Accelerator Laboratory			
Advanced Scientific Computing Research	1,255	—	—
High Energy Physics	326,630	320,367	349,678
Nuclear Physics	172	—	—
Fusion Energy Sciences	3	—	—
Science Laboratories Infrastructure	491	—	—
Workforce Development for Teachers and Scientists	50	308	300
Safeguards and Security	3,043	3,221	3,221
Total, Fermi National Accelerator Laboratory	331,644	323,896	353,199
Fermi Site Office			
Science Program Direction	2,235	2,346	2,496
Golden Field Office			
Basic Energy Sciences	4	4	4
Advanced Scientific Computing Research	3	—	—
Biological and Environmental Research	3	—	—
High Energy Physics	4	—	—
Nuclear Physics	3	—	—
Fusion Energy Sciences	3	—	—
Workforce Development for Teachers and Scientists	637	835	880
Total, Golden Field Office	657	839	884
Idaho National Laboratory			
Basic Energy Sciences	457	225	345
Biological and Environmental Research	1,611	1,190	867
Fusion Energy Sciences	2,380	2,334	2,322
Workforce Development for Teachers and Scientists	70	340	345
Total, Idaho National Laboratory	4,518	4,089	3,879

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Lawrence Berkeley National Laboratory			
Basic Energy Sciences	112,758	125,497	142,361
Advanced Scientific Computing Research	74,684	77,559	84,259
Biological and Environmental Research	74,111	72,671	68,807
High Energy Physics	46,303	44,812	41,831
Nuclear Physics	19,518	20,706	23,004
Fusion Energy Sciences	5,325	4,911	4,926
Science Laboratories Infrastructure	15,009	21,500	13,145
Workforce Development for Teachers and Scientists	673	885	804
Safeguards and Security	4,743	4,981	4,981
Total, Lawrence Berkeley National Laboratory	353,124	373,522	384,118
Lawrence Livermore National Laboratory			
Basic Energy Sciences	3,776	2,854	3,581
Advanced Scientific Computing Research	8,198	1,800	1,800
Biological and Environmental Research	24,154	25,209	22,455
High Energy Physics	2,266	2,196	2,174
Nuclear Physics	820	905	975
Fusion Energy Sciences	13,423	12,025	12,004
Science Laboratories Infrastructure	150	—	—
Workforce Development for Teachers and Scientists	—	78	200
Total, Lawrence Livermore National Laboratory	52,787	45,067	43,189
Los Alamos National Laboratory			
Basic Energy Sciences	27,662	21,993	21,490
Advanced Scientific Computing Research	4,052	2,075	2,075
Biological and Environmental Research	18,385	15,479	14,633
High Energy Physics	581	590	608
Nuclear Physics	8,421	10,515	12,260
Fusion Energy Sciences	4,024	3,356	3,042
Workforce Development for Teachers and Scientists	50	361	350
Total, Los Alamos National Laboratory	63,175	54,369	54,458

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
National Energy Technology Laboratory			
Basic Energy Sciences	12	—	—
Fusion Energy Sciences	125	—	—
Science Laboratories Infrastructure	275	—	—
Workforce Development for Teachers and Scientists	433	500	810
Total, National Energy Technology Laboratory	845	500	810
National Renewable Energy Laboratory			
Basic Energy Sciences	8,187	7,403	7,718
Advanced Scientific Computing Research	556	150	150
Biological and Environmental Research	584	875	594
Workforce Development for Teachers and Scientists	44	—	—
Total, National Renewable Energy Laboratory	9,371	8,428	8,462
NNSA Service Center/Albuquerque			
Biological and Environmental Research	800	—	—
Safeguards and Security	130	—	—
Total, NNSA Service Center/Albuquerque	930	—	—
New Brunswick Laboratory			
Science Program Direction	—	—	6,644
Oak Ridge Institute for Science and Education			
Basic Energy Sciences	3,401	810	660
Advanced Scientific Computing Research	1,584	—	—
Biological and Environmental Research	4,636	4,159	3,754
High Energy Physics	384	—	165
Nuclear Physics	770	703	673
Fusion Energy Sciences	1,225	788	1,400
Science Laboratories Infrastructure	768	—	—
Science Program Direction	117	—	—
Workforce Development for Teachers and Scientists	1,557	1,545	1,582
Safeguards and Security	1,359	1,489	1,489
Total, Oak Ridge Institute for Science and Education	15,801	9,494	9,723

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		
Oak Ridge National Laboratory			
Basic Energy Sciences	283,857	322,480	319,004
Advanced Scientific Computing Research	64,020	82,822	79,822
Biological and Environmental Research	42,270	36,266	31,844
High Energy Physics	225	182	289
Nuclear Physics	20,347	23,349	23,896
Fusion Energy Sciences	40,050	18,650[a]	177,236
Science Laboratories Infrastructure	1,283	8,047	8,618
Safeguards and Security	9,219	8,396	8,396
Total, Oak Ridge National Laboratory	461,271	500,192	649,105
Oak Ridge Office			
Basic Energy Sciences	80	80	80
Advanced Scientific Computing Research	80	—	—
Biological and Environmental Research	677	373	423
High Energy Physics	16	80	80
Nuclear Physics	532	—	—
Fusion Energy Sciences	80	—	90
Science Laboratories Infrastructure	5,028	5,079	5,079
Science Program Direction	42,534	44,252	44,150
Workforce Development for Teachers and Scientists	90	90	90
Safeguards and Security	16,286	17,975	17,975
Total, Oak Ridge Office	65,403	67,929	67,967

[a] $60,000,000 of FY 2007 ITER funding is reflected in the Princeton Plasma Physics Laboratory (PPPL), consistent with the FY 2007 request to Congress. FY 2006 and FY 2008 ITER funding is reflected within the Oak Ridge National Laboratory (ORNL).

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Pacific Northwest National Laboratory			
Basic Energy Sciences	15,587	15,182	15,183
Advanced Scientific Computing Research	8,164	350	350
Biological and Environmental Research	84,137	85,695	84,103
Fusion Energy Sciences	1,285	815	898
Science Laboratories Infrastructure	4,950	—	—
Workforce Development for Teachers and Scientists	882	1,035	947
Safeguards and Security	10,285	10,993	10,993
Total, Pacific Northwest National Laboratory	125,290	114,070	112,474
Pacific Northwest Site Office			
Science Program Direction	5,388	5,553	5,353
Princeton Plasma Physics Laboratory			
Advanced Scientific Computing Research	1,171	—	—
High Energy Physics	225	249	266
Fusion Energy Sciences	71,745	129,956[a]	71,647
Science Laboratories Infrastructure	119	—	—
Workforce Development for Teachers and Scientists	115	392	430
Safeguards and Security	1,919	1,953	2,053
Total, Princeton Plasma Physics Laboratory	75,294	132,550	74,396
Princeton Site Office			
Science Program Direction	1,618	1,668	1,759

[a] $60,000,000 of FY 2007 ITER funding is reflected in PPPL, consistent with the FY 2007 request to Congress. FY 2006 and FY 2008 ITER funding is reflected within ORNL.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Sandia National Laboratories			
Basic Energy Sciences	34,353	43,822	43,453
Advanced Scientific Computing Research	5,611	2,595	2,595
Biological and Environmental Research	4,610	4,213	1,100
Nuclear Physics	25	—	—
Fusion Energy Sciences	2,389	1,655	1,665
Workforce Development for Teachers and Scientists	—	258	455
Total, Sandia National Laboratories	46,988	52,543	49,268
Savannah River National Laboratory			
Basic Energy Sciences	300	200	300
Biological and Environmental Research	934	691	321
Fusion Energy Sciences	20	—	—
Workforce Development for Teachers and Scientists	—	258	230
Total, Savannah River National Laboratory	1,254	1,149	851
Savannah River Operations Office			
Biological and Environmental Research	1,102	—	—
Stanford Linear Accelerator Center			
Basic Energy Sciences	152,942	215,469	190,498
Advanced Scientific Computing Research	102	—	—
Biological and Environmental Research	4,695	4,311	4,419
High Energy Physics	146,064	145,964	114,627
Science Laboratories Infrastructure	5,539	5,770	—
Workforce Development for Teachers and Scientists	140	150	303
Safeguards and Security	2,377	2,437	2,437
Total, Stanford Linear Accelerator Center	311,859	374,101	312,284
Stanford Site Office			
Science Program Direction	1,625	2,134	2,551

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Thomas Jefferson National Accelerator Facility			
Advanced Scientific Computing Research	120	—	—
Biological and Environmental Research	537	400	400
High Energy Physics	912	927	350
Nuclear Physics	78,358	96,371	102,437
Science Laboratories Infrastructure	175	—	—
Workforce Development for Teachers and Scientists	328	502	450
Safeguards and Security	1,231	1,311	1,311
Total, Thomas Jefferson National Accelerator Facility	81,661	99,511	104,948
Thomas Jefferson Site Office			
Science Program Direction	1,457	1,500	1,872
Washington Headquarters			
Basic Energy Sciences	2,093	189,160	238,552
Advanced Scientific Computing Research	918	104,403	115,351
Biological and Environmental Research	2,006	137,076	187,094
High Energy Physics	1,726	99,639	103,313
Nuclear Physics	1,015	32,910	34,857
Fusion Energy Sciences	616	13,683	13,203
Science Laboratories Infrastructure	277	175	35,275
Science Program Direction	68,038	75,045	80,741
Workforce Development for Teachers and Scientists	—	119	410
Safeguards and Security	96	437	237
Total, Washington Headquarters	76,785	652,647	809,033
Total, Science	3,637,649	4,107,315	4,403,481

Major Changes or Shifts by Site

Argonne National Laboratory

Basic Energy Sciences

- The **Center for Nanoscale Materials**, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2008.

Advanced Scientific Computing Research

- The Leadership Computing Facility will be expanded to provide high-performance computing capability with low electrical power consumption to enable scientific advances.

Lawrence Berkeley National Laboratory

Basic Energy Sciences

- The Molecular Foundry, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2008.
- Advanced Light Source (ALS) User Support Building (USB) will begin construction in FY 2008. The USB will provide user support space to accommodate the growth in the number of users and future expansion of the ALS.

Brookhaven National Laboratory

Basic Energy Sciences

- The **Center for Functional Nanomaterials**, one of five DOE Nanoscale Science Research Centers, will begin operations in FY 2008.

Los Alamos National Laboratory

Basic Energy Sciences

- The **Center for Integrated Nanotechnologies**, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2008.

Oak Ridge National Laboratory

Basic Energy Sciences

- Construction of the **Spallation Neutron Source** (SNS) was completed on June 6, 2006. Over the next two to three years, the facility will continue to fabricate and commission instruments, funded both as part of the SNS project and from other sources including non-DOE sources, and will increase power to full levels. A new Major Item of Equipment to be initiated in FY 2007 will allow the fabrication of approximately four to five additional instruments for the SNS, thus nearly completing the initial suite of 24 instruments that can be accommodated in the high-power target station.
- The **Center for Nanophase Materials Sciences**, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2008.

Fusion Energy Sciences

- In July 2004, a Oak Ridge National Laboratory (ORNL)/Princeton Plasma Physics Laboratory (PPPL) team was selected to host the U.S. ITER Project Office. In January 2006, based on the management successes of the SNS, ORNL was chosen as the lead laboratory to manage the U.S. Contributions to ITER, Major Item of Equipment project. ORNL has established an excellent Project Office team to manage the domestic activities and to engage the U.S. fusion community and industry to provide for the U.S. hardware contributions and personnel to the ITER Organization in Cadarache, France. ORNL has maintained active involvement in the international ITER Project activities in order to ensure consistency with the international and domestic project activities and schedule. There will be significant international cooperation between the U.S. ITER Project Office, the international ITER Organization, and other ITER parties.

Princeton Plasma Physics Laboratory

Fusion Energy Sciences

- In January 2006, based on the management successes of the Spallation Neutron Source, ORNL was chosen to replace PPPL as the lead laboratory to manage the U.S. Contributions to ITER, Major Item of Equipment project. PPPL continues to provide significant contributions to the ITER Preparations and the transition and startup of the U.S. Contributions to ITER project. PPPL is identified as a participating laboratory responsible for significant project activities of the U.S. ITER Project Office. There will be significant international cooperation and coordination between the U.S. ITER Project Office, the international ITER Organization, and other ITER parties.

New Brunswick Laboratory

Science Program Direction

- Beginning in FY 2008, New Brunswick Laboratory (NBL) is funded and administered by the Office of Science through the Chicago Office. Prior to FY 2008, the Office of Environment, Safety and Health funded NBL.

Sandia National Laboratories

Basic Energy Sciences

- The **Center for Integrated Nanotechnologies**, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2008.

Stanford Linear Accelerator Center

Basic Energy Sciences and High Energy Physics

- Funding is provided by both Basic Energy Sciences and High Energy Physics to support operation of the Stanford Linear Accelerator Center (SLAC) linac. FY 2008 marks the third and final year of the transition from High Energy Physics to Basic Energy Sciences for SLAC linac operations funding, as B-factory operations complete in FY 2008 and the Linac Coherent Light Source operations start in FY 2009.

Site Description

Ames Laboratory

Introduction

The Ames Laboratory is a program dedicated laboratory (Basic Energy Sciences). The laboratory is located on the campus of the Iowa State University, in Ames, Iowa, and consists of 12 buildings (327,664 gross square feet of space) with the average age of the buildings being 38 years. DOE does not own the land. Ames conducts fundamental research in the physical, chemical, and mathematical sciences associated with energy generation and storage and is a national center for the synthesis, analysis, and engineering of rare-earth metals and their compounds.

Basic Energy Sciences

Ames 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. Ames also supports theoretical studies for the prediction of molecular energetics and chemical reaction rates and provides leadership in analytical and separations chemistry.

Ames 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.

Advanced Scientific Computing Research

Ames conducts research in computer science and participates on Scientific Discovery through Advanced Computing (SciDAC) science application teams.

Science Laboratories Infrastructure

The Science Laboratories Infrastructure (SLI) program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

This program coordinates planning, policy, implementation, and oversight in the areas of security systems, protective forces, personnel security, program management, 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-through, monitoring of electronic alarm systems, and emergency communications.

Ames Site Office

The Ames Site Office provides the single federal presence with responsibility for contract performance at the Ames Laboratory. This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Argonne National Laboratory

Introduction

The Argonne National Laboratory (ANL) in Argonne, Illinois, is a multiprogram laboratory located on 1,500 acres in suburban Chicago. The laboratory consists of 99 buildings (4.4 million gross square feet of space) with an average building age of 35 years.

Basic Energy Sciences

ANL is home to research activities in broad areas of materials and chemical sciences. It is also the site of four user facilities—the Advanced Photon Source (APS), the Intense Pulsed Neutron Source (IPNS), the Center for Nanoscale Materials (CNM), and the Electron Microscopy Center (EMC) for Materials Research.

The **Advanced Photon Source** is one of only three third-generation, hard x-ray synchrotron radiation light sources in the world. 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 short-pulsed spallation neutron source that first operated all of its instruments in the user mode in 1981. Twelve neutron beam lines serve 14 instruments. 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. 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 **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. Research at EMC includes microscopy based studies on high-temperature superconducting materials, irradiation effects in metals and semiconductors, phase transformations, and processing related structure and chemistry of interfaces in thin films.

The **Center for Nanoscale Materials** provides capabilities for developing new methods for self assembly of nanostructures, exploring the nanoscale physics and chemistry of nontraditional electronic materials, and creating new probes for exploring nanoscale phenomena. The CNM is organized around six scientific themes: nanomagnetism, bio-inorganic hybrids, nanocarbon, complex oxides, nanophotonics, and theory and simulation.

Advanced Scientific Computing Research

ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. ANL also participates in scientific application partnerships and contributes to a number of the SciDAC science application teams. Further, it participates in both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers. As part of the LCF activity, the ANL facility will be upgraded to 250-500 teraflops of high-performance computing with low electrical power consumption by the end of FY 2008 to advance science and will continue to focus on testing and evaluating leading edge computers.

Biological and Environmental Research

ANL conducts research on the molecular control of genes and gene pathways in microbes in addition to biological and geochemical research that supports environmental remediation. ANL operates beamlines for protein crystallography at the APS and also supports a growing community of users in environmental sciences.

In support of climate change research, ANL has oversight responsibility for coordinating the overall infrastructure operations of all three stationary Atmospheric Radiation Measure (ARM) sites to ensure consistency, data quality, and site security and safety. This includes infrastructure coordination of: communications, data transfer, and instrument calibration. ANL also provides the site manager for the Southern Great Plains site who is responsible for coordinating the day-to-day operations at that site. ANL also conducts research on aerosol processes and properties, and develops and applies software to enable efficient long-term climate simulations on distributed-memory multiprocessor computing platforms. In conjunction with ORNL, PNNL, and six universities, ANL is a participating laboratory in the Carbon Sequestration in Terrestrial Ecosystems (CSiTE) consortium, focusing on research to understand the processes controlling the rate of soil carbon accretion.

High Energy Physics

The High Energy Physics (HEP) program supports physics research and technology R&D at ANL, using unique capabilities of the laboratory in the areas of engineering and detector technology and advanced accelerator and computing techniques.

Nuclear Physics

The major ANL activity is the operation and R&D program at the Argonne Tandem Linac Accelerator System (ATLAS) National User Facility. Other activities include an on-site program of research using laser techniques (Atom Trap Trace Analysis); research programs at the Thomas Jefferson National Accelerator Facility (TJNAF), Fermi National Laboratory (Fermilab), Relativistic Heavy Ion Collider (RHIC), and Deutsches Elektronen-Synchrotron (DESY) in Germany investigating the structure of the nucleon; generic R&D in rare isotope beam development relevant for a next generation facility in nuclear structure and astrophysics; theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Low Energy physics; and data compilation and evaluation activities as part of the National Nuclear Data Program.

The **Argonne Tandem Linac Accelerator System** National User 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 10 to 20% of the beams are exotic (rare isotope) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus, the Advanced Penning Trap. The Gammasphere detector, 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 staff are world leaders in superconducting linear accelerator technology, with particular application in rare isotope beam facilities. The combination of versatile beams and powerful instruments enables about 400 users annually at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies. The capabilities of ATLAS are being augmented by the fabrication of a Californium source to provide new capabilities in neutron-rich radioactive beams.

Fusion Energy Sciences

Argonne contributes to the plasma facing components area of the enabling R&D program activities, focusing on modeling of plasma-materials interaction phenomena of interest for ITER and current plasma experiments.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

This 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, program management, and personnel security. In addition, a protective force is maintained. These activities ensure that the facility, personnel, and assets remain safe from potential threats.

Argonne Site Office

The Argonne Site Office provides the single federal presence with responsibility for contract performance at the Argonne National Laboratory (ANL). This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Berkeley Site Office

The Berkeley Site Office provides the single federal presence with responsibility for contract performance at the Lawrence Berkeley National Laboratory (LBNL). This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Brookhaven National Laboratory

Introduction

The Brookhaven National Laboratory (BNL) is a multiprogram laboratory located on 5,300 acres in Upton, New York. The laboratory consists of 336 SC buildings (3.8 million gross square feet of space) with an average building age of 36 years. 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.

Basic Energy Sciences

BNL conducts research efforts in materials and chemical sciences as well as to efforts in geosciences and biosciences. It is also the site of one BES supported user facilities—the National Synchrotron Light Source (NSLS).The **National Synchrotron Light Source** 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, 7 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.

Advanced Scientific Computing Research

BNL conducts basic research in applied mathematics and participates on SciDAC science application teams. It also participates in SciDAC Centers for Enabling Technologies that focus on specific software challenges confronting users of petascale computers.

Biological and Environmental Research

BNL operates beam lines for protein crystallography at the NSLS 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 in support of the Genomics: GTL program and on the molecular mechanisms of cell responses to low doses of radiation. BNL conducts molecular nuclear medicine research developing advanced medical imaging technologies including radiopharmaceuticals for medical imaging. The 2005 BER Distinguished Scientist for Medical Sciences is at BNL.

Climate change research includes 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 (ASP), including providing special expertise in conducting atmospheric field campaigns and aerosol research. The ASP chief scientist is at BNL. BNL scientists play a leadership role in the operation of the Free-Air Carbon Dioxide Enrichment (FACE) experiment at the Duke Forest which seeks to understand how plants respond to elevated carbon dioxide concentrations in the atmosphere.

BNL supports environmental remediation sciences research and is participating in the National Science Foundation (NSF)/DOE Environmental Molecular Sciences Institute at the State University of New York-Stony Brook and has instituted a new internal initiative, EnviroSuite, to support a growing community of environmental users who are supported at NSLS.

High Energy Physics

The HEP program supports physics research and technology research and development (R&D) at BNL, using unique resources of the laboratory, including engineering and technology for future accelerators and detectors, computational resources, and the Accelerator Test Facility.

Nuclear Physics

Research activities include use of relativistic heavy-ion beams and polarized protons in the Relativistic Heavy Ion Collider (RHIC) to investigate hot, dense nuclear matter and to understand the internal "spin" structure of the proton, respectively—parts of which are coordinated with the RIKEN BNL Research Center funded by Japan; development of future detectors for RHIC; R&D of electron-cooling accelerator technology aimed at increasing the RHIC beam luminosity; a small exploratory research activity directed towards the heavy ion program at the Large Hadron Collider (LHC); research on the properties of neutrinos at the Sudbury Neutrino Observatory (SNO); a theory program emphasizing RHIC heavy ion and "spin" physics; and data compilation and evaluation at the National Nuclear Data Center (NNDC) that is the central U.S. site for these national and international efforts.

The **Relativistic Heavy Ion Collider** Facility, completed in 1999, is a major unique international facility currently used by about 1,200 scientists from 19 countries. RHIC uses 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 kilometers circumference with 6 intersection regions where the beams can collide. It can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC is being used to search for the predicted "quark-gluon plasma," a form of nuclear matter thought to have existed microseconds after the "Big Bang." It can also collide polarized protons with beams of energy up to 250 GeV per nucleon—a unique capability. Four detectors were fabricated to provide complementary measurements, with some overlap in order to cross-calibrate the measurements. (1) The core of the Solenoidal Tracker at RHIC (STAR) detector 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) and end-cap calorimeter measure deposited energy for high-energy charged and neutral particles and contain particle-photon discrimination capability. Other ancillary detector systems include a Silicon Vertex Tracker and forward particle tracking capabilities. A barrel Time of Flight detector upgrade (STAR TOF) is being added to significantly extend the particle identification capability of STAR detector. (2) The Pioneering High-Energy Nuclear Interacting eXperiment (PHENIX) detector has a particular focus on the measurement of rare probes at high event detection rate. It consists of two transverse spectrometer arms that can track charged particles within a magnetic field, especially to higher momentum: it provides excellent discrimination among photons, electrons, and hadrons. There are also two large muon tracking and identification systems in the forward and backward directions as well as ancillary tracker systems. Scientists using the other two smaller detectors, Phobos and Broad RAnge Hadron Magnetic Spectrometer (BRAHMS), have completed their data acquisition programs and focus on data analysis. International participation has been essential in the implementation of all four detector systems.

The **Alternating Gradient Synchrotron** 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. The AGS is also utilized for radiation damage studies of 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, is providing heavy-ion beams to a dedicated beam line (NASA Space Radiation Laboratory) for biological and electronic systems radiation studies funded by NASA. The incremental costs for these studies are provided by NASA.

The **Tandem Van de Graaff** accelerators which serve as injectors for the Booster Synchrotron will be replaced by a modern, compact Electron Beam Ion Source (EBIS) and linac system which promises greater efficiency, greater reliability, and lower maintenance costs as well as the potential for future upgrades. The EBIS is a joint DOE/NASA project.

The **National Nuclear Data Center** 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 for a very broad user community in all aspects of nuclear technology, with relevance to homeland security. Nuclear Data program-funded scientists at U.S. national laboratories and universities contribute to the activities and responsibilities of the NNDC.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

The Safeguards and Security (S&S) program activities are focused on protective forces, cyber security, personnel security, security systems, information security, program management, 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 site's special nuclear materials.

Brookhaven Site Office

The Brookhaven Site Office provides the single federal presence with responsibility for contract performance at the Brookhaven National Laboratory (BNL). This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Chicago Office

Introduction

The Chicago (CH) Office supports the Department's programmatic missions in Science and Technology, National Nuclear Security, Energy Resources, and Environmental Quality by providing expertise and assistance in such areas as contract management, procurement, project management, engineering, facilities and infrastructure, property management, construction, human resources, financial management, general and patent law, environmental protection, quality assurance, integrated safety management, integrated safeguards and security management, nuclear material control and accountability, and emergency management. CH directly supports site offices responsible for program management oversight of seven major management and operating laboratories—Ames Laboratory, Argonne National Laboratory, Lawrence Berkeley National Laboratory, Brookhaven National Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, and Stanford Linear Accelerator Center—and one government-owned and government-operated Federal laboratory, New Brunswick Laboratory. Additionally, the administrative, business, and technical expertise of CH is shared SC-wide through the Integrated Support Center concept. CH serves as SC's grant center, administering grants to 272 colleges/universities in all 50 states, Washington, D.C., and Puerto Rico, as determined by the DOE-SC program offices as well as non-SC offices.

Basic Energy Sciences

The BES program funds research at 190 academic institutions located in 48 states.

Advanced Scientific Computing Research

The Advanced Scientific Computing Research (ASCR) program funds research at over 70 colleges/ universities supporting over 130 principal investigators.

Biological and Environmental Research

The Biological and Environmental Research (BER) program funds research at some 220 institutions, including colleges/universities, private industry, and other federal and private research institutions located in 44 states.

High Energy Physics

The HEP 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.

Nuclear Physics

The Nuclear Physics (NP) program funds 190 research grants at 85 colleges/universities located in 34 states and the District of Columbia. Among these are grants with the Triangle Universities Nuclear Laboratory (TUNL) which includes the High Intensity Gamma Source (HIGS) at the Duke Free Electron Laser Laboratory; Texas A&M (TAMU) Cyclotron; the Yale Tandem Van de Graaff; University of Washington Center for Experimental Nuclear and Particle Astrophysics (CENPA) and the Institute for Nuclear Theory (INT); and the Research and Engineering (R&E) Center at the Massachusetts Institute for Technology. The first three of these include accelerator facilities which 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. The CENPA and R&E Center have unique infrastructure ideal for pursuing instrumentation projects important to the NP mission. The Institute for Nuclear Theory (INT) is a premier international center for new initiatives and collaborations in nuclear theory research.

Fusion Energy Sciences

The Chicago Office supports the Fusion Energy Sciences (FES) program by implementing grants and cooperative agreements for research at more than 50 colleges and universities located in approximately 30 states. It also supports the FES program by implementing a cooperative agreement and grants for the DIII-D tokamak experiment and related programs at General Atomics, an industrial firm located in San Diego, California.

Fermi National Accelerator Laboratory

Introduction

Fermi National Accelerator Laboratory is a program-dedicated laboratory (High Energy Physics) located on a 6,800-acre site in Batavia, Illinois. The laboratory consists of 346 buildings (2.3 million gross square feet of space) with an average building age of 40 years. Fermilab is the largest U.S. laboratory for research in high-energy physics and is second only to CERN, the European Laboratory for Particle Physics. About 2,200 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 understand matter at its deepest level, to identify its fundamental building blocks, and to understand how the laws of nature determine their interactions.

Advanced Scientific Computing Research

Fermilab participates in some SciDAC science application teams and in SciDAC Centers for Enabling Technologies that focus on specific software challenges confronting users of petascale computers.

High Energy Physics

Fermilab is the principal experimental facility for HEP. 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 Collider is the highest energy proton accelerator in the world, and will remain so until the LHC begins operation at CERN late this decade. The Tevatron complex also includes the **Neutrinos at the Main Injector (NuMI)** beamline, the world’s highest intensity neutrino beam facility, which started operation in 2005. The HEP program also supports physics research and technology R&D at Fermilab, using unique resources of the laboratory, including state-of-the-art engineering and technology for future generations of accelerators and detectors and computational resources.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

S&S program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility, and toward continuing the cyber security, program management, security systems, and material control and accountability programs to accurately account for and protect the facility's special nuclear materials.

Fermi Site Office

The Fermi Site Office provides the single federal presence with responsibility for contract performance at the Fermi National Accelerator Laboratory (Fermilab). This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Idaho National Laboratory

Introduction

Idaho National Laboratory (INL) is a multiprogram laboratory located on 572,000 acres in Idaho Falls, Idaho. Within the laboratory complex are nine major applied engineering, interim storage, and research and development facilities.

Basic Energy Sciences

INL supports studies to understand and improve the life expectancy of material systems used in engineering.

Advanced Scientific Computing Research

INL participates in SciDAC science application teams.

Biological and Environmental Research

INL is conducting research in subsurface science relating to clean up of the nuclear weapons complex with an emphasis on understanding coupled processes affecting contaminant transport.

Fusion Energy Sciences

Since 1978, INL has been the lead laboratory for fusion safety. As such, 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 INL focuses on the safety aspects of magnetic fusion concepts for existing and future machines, such as a burning plasma experiment, and further developing our domestic safety database using existing collaborative arrangements to conduct work on international facilities. In addition, INL has expanded their research and facilities capabilities to include tritium science activities. INL has completed fabrication of the Safety and Tritium Applied Research (STAR) Facility, which is a small tritium laboratory where the fusion program can conduct tritium material science, chemistry, and safety experiments. The STAR Facility has been declared a National User Facility. INL also coordinates codes and standards within the ITER program.

Lawrence Berkeley National Laboratory

Introduction

The Lawrence Berkeley National Laboratory is a multiprogram laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The laboratory consists of 107 buildings (1.5 million gross square feet of space) with an average building age of 37 years. LBNL is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. The land is leased from the University of California.

Basic Energy Sciences

LBNL is home to 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. It is also the site of three Basic Energy Sciences (BES) supported user facilities—the Advanced Light Source (ALS), the Molecular Foundry, and the National Center for Electron Microscopy (NCEM).

The **Advanced Light Source** provides vacuum-ultraviolet light and x-rays 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 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 has already been applied to make important discoveries in a wide variety of scientific disciplines. An ALS User Support Building (USB) will begin construction in FY 2008. The USB will provide high-quality user support space in sufficient quantity to accommodate the very rapid growth in the number of ALS users and to accommodate projected future expansion. The USB will contain staging areas for ALS experiments, space for a long beamline that will extend from the floor of the ALS into the USB, and temporary office space for visiting users.

The **National Center for Electron Microscopy** provides instrumentation for high-resolution, electron-optical microcharacterization of atomic structure and composition of metals, ceramics, semiconductors, superconductors, and magnetic materials. This facility contains one of the highest resolution electron microscopes in the U.S.

The **Molecular Foundry** provides users with instruments, techniques, and collaborators to enhance the study of the synthesis, characterization, and theory of nanoscale materials. Its focus is on the multidisciplinary development and understanding of both “soft” (biological and polymer) and “hard” (inorganic and microfabricated) nanostructured building blocks and the integration of these building blocks into complex functional assemblies. Scientific themes include inorganic nanostructures; nanofabrication; organic, polymer, and biopolymer nanostructures; biological nanostructures; imaging and manipulation of nanostructures; and theory of nanostructures. The facility offers expertise in a variety of techniques for the study of nanostructures, including electronic structure and excited-state methods, *ab initio* and classical molecular dynamics, quantum transport, and classical and quantum Monte Carlo approaches. Several research laboratories at LBNL with capabilities that complement those at the facilities also are open to Foundry users.

Advanced Scientific Computing Research

LBNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. LBNL also participates in several SciDAC science application teams, and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers. LBNL manages the ESnet. ESnet is one of the worlds most effective and progressive science-related computer networks that provides worldwide access and communications to Department of Energy facilities. LBNL is also the site of the National Energy Research Scientific Computing Center (NERSC), which 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.

Biological and Environmental Research

LBNL is one of the major national laboratory partners forming the Joint Genome Institute (JGI), the principal goal of which is high-throughput DNA sequencing techniques. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on microbial systems biology research as part of Genomics: GTL program. The Chief Scientist for the Low Dose Radiation Research program and the 2005 BER Distinguished Scientists for Environmental Remediation and for Life Sciences are at LBNL. LBNL operates beam lines for determination of protein structure at the ALS for use by the national and international biological research community. The ALS also supports and is used by a growing environmental science community. LBNL supports environmental remediation sciences research and provides geophysical, biophysical, and biochemical research capabilities for field sites in that program and is participating in the NSF/DOE Environmental Molecular Sciences Institute at Pennsylvania State University.

LBNL conducts research on carbon cycling and carbon sequestration on terrestrial ecosystems. It also conducts research on biological and ecological responses to climatic and atmospheric changes.

It also develops scalable implementation technologies that allow widely used climate models to run effectively and efficiently on massively parallel processing supercomputers. LBNL also conducts research on terrestrial carbon cycling to understand the processes controlling the exchange of CO_2 between terrestrial ecosystems and the atmosphere.

High Energy Physics

The HEP program supports physics research and technology R&D at LBNL, using unique capabilities of the laboratory in the areas of superconducting magnet R&D, engineering and detector technology, world-forefront expertise in laser driven particle acceleration, expertise in design of advanced electronic devices, computational resources, and design of modern, complex software codes for HEP experiments.

Nuclear Physics

LBNL supports a variety of activities focused primarily in the low energy and heavy ion NP subprograms. These include fabrication of a next-generation gamma-ray detector system, GRETINA; research with the STAR detector located at Brookhaven’s RHIC facility; development of future detector systems for RHIC; operation of the Parallel Distributed Systems Facility aimed at heavy ion and low energy physics computation; fabrication activities directed towards a detector upgrade for the ALICE detector heavy ion program at the Large Hadron Collider (LHC) at Organisation Européanne pour la Recherche Nucléaire (CERN); operation of the Sudbury Neutrino Observatory (SNO) detector in Canada and the KamLAND detector in Japan that are performing neutrino studies; development of next generation neutrino detectors; a theory program with an emphasis on relativistic heavy ion physics; data compilation and evaluation activities supporting the National Nuclear Data Center at BNL; and a technical effort in generic R&D of rare isotope beam development with the development of electron-cyclotron resonance (ECR) ion sources. The 88-Inch Cyclotron at the LBNL is a facility for testing electronic circuit components for radiation "hardness" to cosmic rays, supported by the National Reconnaissance Office (NRO) and the U.S. Air Force (USAF), and for a small in-house research program supported by NP.

Fusion Energy Sciences

LBNL has been conducting research in developing ion beams for applications to high energy density physics in the near term (4 to 10 years) and inertial fusion energy in the long term. Currently the laboratory has two major experimental systems for doing this research: the Neutralized Drift Compression Experiment (NDCX) and the High Current Experiment (HCX). Both experiments are directed at answering the question of how ion beams can be produced with the intensity required for research in high energy density physics and inertial fusion. LBNL conducts this research together with the Lawrence Livermore National Laboratory and Princeton Plasma Physics Laboratory through the Heavy Ion Fusion Science Virtual National Laboratory.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

This program provides physical protection of personnel and laboratory facilities. This is accomplished with protective forces, security systems, cyber security, program management, personnel security, and material control and accountability of special nuclear material.

Lawrence Livermore National Laboratory

Introduction

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.

Basic Energy Sciences

LLNL supports research in materials sciences and in geosciences research on the sources 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.

Advanced Scientific Computing Research

LLNL participates in base applied mathematics and computer science research. LLNL also participates in several SciDAC science application teams and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers.

Biological and Environmental Research

LLNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI), the principal goal of which is high-throughput DNA sequencing. LLNL is developing new biocompatible materials and microelectronics for the artificial retina project. It also conducts research on the molecular mechanisms of cell responses to low doses of radiation.

Through the program for Climate Model Diagnosis and Intercomparison, LLNL provides the international leadership to develop and apply diagnostic tools to evaluate the performance of climate models and to improve them. Virtually every climate modeling center in the world participates in this unique program. It also conducts research to improve understanding of the climate system, particularly the climate effect of clouds and aerosol properties and processes and climate change feedbacks on carbon cycling. The 2005 BER Distinguished Scientist for Climate Change Research is at LLNL.

High Energy Physics

The HEP program supports physics research and technology R&D at LLNL, using unique capabilities of the laboratory primarily in the areas of engineering and detector technology and advanced accelerator R&D.

Nuclear Physics

The LLNL program supports research in relativistic heavy ion physics as part of the PHENIX collaboration at RHIC and the ALICE experiment at the CERN LHC, in nuclear data and compilation activities, in R&D of neutrinoless double beta decay experiments, on theoretical nuclear structure studies, and a technical effort involved in generic R&D of rare isotope beam development.

Fusion Energy Sciences

LLNL works with LBNL and PPPL through the Heavy-Ion Fusion Virtual National Laboratory in advancing the physics of heavy ion beams as a driver for inertial fusion energy in the long term and high energy density physics in the near term. It also conducts research in the concept of Fast Ignition for applications in high energy density physics and inertial fusion energy. 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 at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. It carries out research in the simulation of turbulence and its effect on transport of heat and particles in magnetically confined plasmas. In addition, LLNL carries out research in support of magnets and plasma chamber and plasma-material interactions.

Science Laboratories Infrastructure

The SLI program enables the cleanup and removal of excess SC facilities at LLNL.

Los Alamos National Laboratory

Introduction

Los Alamos National Laboratory (LANL) is a multiprogram laboratory located on 27,000 acres in Los Alamos, New Mexico.

Basic Energy Sciences

LANL is home to a few efforts in materials sciences, chemical sciences, geosciences, and engineering. LANL 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.

Research is also supported 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.

LANL is also the site of two BES supported user facilities: the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center) and the Center for Integrated Nanotechnologies (CINT).

The **Manuel Lujan Jr. Neutron Scattering Center** provides an intense pulsed source of neutrons to a variety of spectrometers for neutron scattering studies. The Lujan Center features instruments for measurement of high-pressure and high-temperature samples, strain measurement, liquid studies, and texture measurement. The facility has a long history and extensive experience in handling actinide samples. A 30 Tesla magnet is also available for use with neutron scattering to study samples in high-magnetic fields. The Lujan Center is part of the Los Alamos Neutron Science Center (LANSCE), which is comprised of a high-power 800-MeV proton linear accelerator, a proton storage ring, production targets to the Lujan Center and the Weapons Neutron Research facility, and a variety of associated experiment areas and spectrometers for national security research and civilian research.

The **Center for Integrated Nanotechnologies** provides tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT is devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. Through its core facility in Albuquerque, New Mexico, and its gateways to both Sandia National Laboratories and Los Alamos National Laboratory, CINT will provide access to tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT supports five scientific thrusts that serve as synergistic building blocks for integration research: nano-bio-micro interfaces, nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and theory and simulation.

Advanced Scientific Computing Research

LANL conducts basic research in mathematics and computer science and in advanced computing software tools. LANL also participates in several SciDAC science application teams, and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers.

Biological and Environmental Research

LANL is one of the major national laboratory partners that comprise the JGI, the principal goal of which is high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. One of LANL's roles in the JGI involves the production of high quality "finished" DNA sequence. It 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 LANSCE for use by the national biological research community. LANL conducts research in optical imaging as part of the artificial retina project

In support of BER's climate change research, LANL manages the day-to-day operations at the Tropical Western Pacific ARM site. In addition, LANL manages the deployment and operation of the ARM mobile facility. LANL also has a crucial role in the development, optimization, and validation of coupled sea ice and oceanic general circulation models and coupling them to atmospheric general circulation models for implementation on massively parallel computers.

LANL also conducts research under environmental remediation sciences with an emphasis on biological processes associated with plutonium mobility in the environment. LANL is participating in the NSF/DOE Environmental Molecular Sciences Institute at Pennsylvania State University.

High Energy Physics

The HEP program supports physics research and technology R&D at LANL, using unique capabilities of the laboratory primarily in the areas of theoretical studies, engineering, and detector technology.

Nuclear Physics

NP supports a broad program of research including: a program of neutron beam research that utilized beams from the LANSCE facility to make fundamental physics measurements (completed in 2007); the fabrication of an experiment to search for the electric dipole moment of the neutron to be located at the Fundamental Neutron Physics Beamline at the SNS; a research and development effort in relativistic heavy ions using the PHENIX detector at the RHIC and development of next generation instrumentation for RHIC; research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and the "spin" structure of nucleons at RHIC using polarized proton beams; research at the Sudbury Neutrino Observatory (SNO) and at MiniBooNE directed at studies of the properties of neutrinos including development of the next generation detector; a broad program of theoretical research; nuclear data and compilation activities as part of the U.S. Nuclear Data program; and a technical effort involved in rare isotope beam development.

Fusion Energy Sciences

LANL has developed a substantial experimental system for research in Magnetized Target Fusion, one of the major innovative confinement concepts in magnetic alternates. The laboratory leads research in a high-density, compact plasma configuration called Field Reversed Configuration. LANL supports the creation of computer codes for modeling the stability of magnetically confined plasmas, including tokamaks and innovative confinement concepts. The work also provides theoretical and computational support for the Madison Symmetric Torus experiment, a proof-of-principle experiment in reversed field pinch at the University of Wisconsin in Madison. LANL develops advanced diagnostics for the National Spherical Torus Experiment (NSTX) at PPPL and other fusion experiments, such as the Rotating Magnetic Field as a current drive mechanism for the Field Reversed Configuration Experiment at the University of Washington in Seattle. The laboratory is also doing research in Inertial Electrostatic Confinement, another innovative confinement concept. LANL also supports the tritium processing activities needed for ITER.

National Renewable Energy Laboratory

Introduction

The 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. 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.

Basic Energy Sciences

NREL supports basic research efforts that underpin this technological emphasis at the laboratory; e.g., on overcoming semiconductor doping limits, novel and ordered semiconductor alloys, and theoretical and experimental studies of properties of advanced semiconductor alloys for prototype solar cells. It also 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.

Advanced Scientific Computing Research

NREL participates in SciDAC science application teams including efforts focused on computational nanoscience.

New Brunswick Laboratory

The New Brunswick Laboratory (NBL) is a government-owned, government-operated center for analytical chemistry and measurement science of nuclear materials. In this role, NBL performs measurements of the elemental and isotopic compositions for a wide range of nuclear materials. The NBL is the U.S. Government's Nuclear Materials Measurements and Reference Materials Laboratory and the National Certifying Authority for nuclear reference materials and measurement calibration standards. NBL provides reference materials, measurement and interlaboratory measurement evaluation services, and technical expertise for evaluating measurement methods and safeguards measures in use at other facilities for a variety of Federal program sponsors and customers. The NBL also functions as a Network Laboratory for the International Atomic Energy Agency. The NBL is administered through and is a part of the Chicago Office.

Oak Ridge Institute for Science and Education

Introduction

The 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 university consortium leveraging the scientific strength of major research institutions to advance science and education by partnering with national laboratories, government agencies, and private industry. ORISE focuses on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists.

Basic Energy Sciences

ORISE supports 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). ORISE provides administrative support for panel reviews and site reviews. It also assists with the administration of topical scientific workshops and provides administrative support for other activities such as for the reviews of 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.

Advanced Scientific Computing Research

ORISE provides administrative support for panel reviews, site reviews, and Advanced Scientific Computing Advisory Committee meetings. It also assists with the administration of topical scientific workshops.

Biological and Environmental Research

ORISE coordinates research fellowship programs and manages the DOE-NSF program supporting graduate students to attend the Lindau Meeting of Nobel Laureates. It also coordinates activities associated with the peer review of the research proposals and applications submitted to BER.

High Energy Physics

ORISE provides support to the HEP program in the area of program planning and review.

Nuclear Physics

ORISE supports the Holifield Radioactive Ion Beam Facility (HRIBF) and its research program through a close collaboration with university researchers using HRIBF.

Fusion Energy Sciences

ORISE supports the operation of the Fusion Energy Sciences Advisory Committee (FESAC) and administrative aspects of some FES program peer reviews. It also acts as an independent and unbiased agent to administer the FES Graduate and Postgraduate Fellowship programs in conjunction with FES, ORO, participating universities, DOE laboratories, and industries.

Science Laboratories Infrastructure

The SLI program enables the cleanup and removal of excess facilities at ORISE.

Safeguards and Security

The S&S program at ORISE 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, program management, personnel security, protective forces, security systems, and cyber security.

Oak Ridge National Laboratory

Introduction

The Oak Ridge National Laboratory is a multiprogram laboratory located on the 24,000 acre reservation at Oak Ridge, Tennessee. The laboratory’s 1,100 acre main site on Bethel Valley Road contains 286 buildings (3.4 million gross square feet of space) with an average building age of 36 years. 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 clean, abundant energy; restore and protect the environment; and contribute to national security. The laboratory supports almost every major Departmental mission in science, defense, energy resources, and environmental quality. It provides world-class scientific research capability while advancing scientific knowledge through such major Departmental initiatives as the Spallation Neutron Source (SNS), the Supercomputing Program, Nanoscience Research, complex biological systems, and ITER. In the defense mission arena, programs include those which protect our Homeland and National Security by applying advanced science and nuclear technology to the Nation’s defense. Through the Nuclear Nonproliferation Program, Oak Ridge supports the development and coordination of the implementation of domestic and international policy aimed at reducing threats, both internal and external, to the U.S. from weapons of mass destruction. The Laboratory also supports various Energy Efficiency and Renewable Energy programs and facilitates the R&D of energy efficiency and renewable energy technologies.

Basic Energy Sciences

ORNL is home to major research efforts in materials and chemical sciences with additional programs in engineering and geosciences. ORNL has perhaps the most comprehensive materials research program in the country. It is also the site of three BES supported user facilities—the Spallation Neutron Source (SNS), which completed construction and began operations in FY 2006; the High Flux Isotope Reactor (HFIR); and the Center for Nanophase Materials Sciences (CNMS).

The **Spallation Neutron Source** is a next-generation short-pulse spallation neutron source for neutron scattering that is significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence. The SNS consists 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 is initially one target station that can accommodate 24 instruments; the potential exists for adding more instruments and a second target station later.

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 **Center for Nanophase Materials Sciences** integrates nanoscale science with neutron science; synthesis science; and theory, modeling, and simulation. Scientific themes include macromolecular complex systems, functional nanomaterials such as carbon nanotubes, nanoscale magnetism and transport, catalysis and nano building blocks, and nanofabrication.

Advanced Scientific Computing Research

ORNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. ORNL also participates in several SciDAC science application teams, and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers. The Center for Computational Sciences (CCS), located at ORNL, provides high-end capability computing services to SciDAC teams and other DOE users. ORNL was selected by DOE to develop Leadership Computing Facility (LCF) for science to revitalize the U.S. effort in high end computing.

Biological and Environmental Research

ORNL has a leadership role in research focused on the ecological aspects of global environmental change. It supports basic research through ecosystem-scale manipulative experiments in the field, through laboratory experiments involving model ecosystems exposed to global change factors, and through development and testing of computer simulation models designed to explain and predict effects of climatic change on the structure and functioning of terrestrial ecosystems. ORNL is the home of a FACE experiment which facilitates research on terrestrial carbon processes and the development of terrestrial carbon cycle models. It also houses the ARM archive, providing data to ARM scientists and to the general scientific community. ORNL, in conjunction with ANL and PNNL and six universities, plays a principle role in the CSiTE consortium which is focusing on research to enhance the capacity, rates, and longevity of carbon sequestration in terrestrial ecosystems. ORNL scientists provide improvement in formulations and numerical methods necessary to improve climate models.

ORNL scientists make important contributions to the environmental remediation sciences research programs, providing special leadership in microbiology applied in the field. ORNL also manages the environmental remediation sciences research Field Research Center (FRC). The FRC is a field site for support of research on the complex interactions between physical and biological process that impact the mobility of metal and radionuclide contaminants in subsurface environments.

ORNL is one of the major national laboratory partners that comprise the JGI, the principal goal of which is high-throughput DNA sequencing. One of ORNL's roles in the JGI involves the annotation (assigning biological functions to genes) of completed genomic sequences and mouse genetics. 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. ORNL conducts microbial systems biology research as part of Genomics: GTL. The laboratory also operates the Laboratory for Comparative and Functional Genomics, or "Mouse House."

High Energy Physics

The HEP program supports a small research effort using unique capabilities of ORNL in the area of advanced accelerator R&D.

Nuclear Physics

The major effort at ORNL is the research, development, and operations of the HRIBF that is operated as a National User Facility. Also supported are a relativistic heavy ion group that is involved in a research program using the PHENIX detector at RHIC and ALICE at the LHC; the development of the Fundamental Neutron Physics Beamline at SNS; a theoretical nuclear physics effort that emphasizes investigations of nuclear structure and astrophysics; nuclear data and compilation activities that support the national nuclear data effort; and a technical effort involved in rare isotope beam development.

The **Holifield Radioactive Ion Beam Facility** 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 235 scientists 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 a broad selection of ions. The HRIBF conducts R&D on targets and ion sources and low energy ion transport for radioactive beams. The capabilities of HRIBF were augmented by the fabrication of the High Power Test Laboratory (HPTL) which provides capabilities unique in the world for the development and testing of new ion source techniques. The fabrication of a second source and transport beam-line (IRIS2) for radioactive ions will improve efficiencies and reliabilities.

Fusion Energy Sciences

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 fusion materials science, 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. The laboratory is also the site of the Controlled Fusion Atomic Data Center and its supporting research programs. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL is also a leader in stellarator theory and design and is a major partner with PPPL on the National Compact Stellarator Experiment (NCSX) being built at PPPL. In July 2004, an ORNL/PPPL team was selected to host the U.S. ITER Project Office. In January 2006, based on the management successes of the Spallation Neutron Source, ORNL was chosen as the lead laboratory to manage the U.S. Contributions to ITER, Major Item of Equipment project.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

The S&S 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 providing 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, tracking, and obtaining closure on findings or deficiencies noted during inspections, surveys, or assessments of S&S programs.

Oak Ridge Office

Introduction

The Oak Ridge (OR) Office directly provides corporate support (i.e., procurement, legal, finance, budget, human resources, and facilities and infrastructure) to site offices responsible for program management oversight of two major management and operating laboratories: Pacific Northwest National Laboratory and Thomas Jefferson National Accelerator Facility. OR also oversees the OR Reservation and other DOE facilities in the City of Oak Ridge. Together on the Reservation and in the City of Oak Ridge there are 32 buildings (184,317 square feet) with an average age of 49 years and a total replacement plant value (RPV) of $29.0 million. The RPV of the roads and other structures on the Reservation is $47.5 million. The OR Financial Service Center provides payment services for the entire Department of Energy/NNSA, nation-wide. The administrative, business, and technical expertise of OR is shared SC-wide through the Integrated Support Center concept. The OR Manager is also the single Federal official with responsibility for contract performance at ORNL and the Oak Ridge Institute for Science and Education (ORISE). The Manager provides on-site presence for ORNL and ORISE with authority encompassing contract management, program and project implementation, Federal stewardship, and internal operations.

Science Laboratories Infrastructure

The Oak Ridge Landlord subprogram maintains Oak Ridge Reservation infrastructure such as roads outside plant fences as well as DOE facilities in the town of Oak Ridge, PILT, and other needs related to landlord responsibilities.

Safeguards and Security

The S&S program provides for contractor protective forces for the Federal office building and ORNL. This includes protection of a category 1 Special Nuclear Material Facility, Building 3019. Other small activities include security systems, information security, and personnel security.

Pacific Northwest National Laboratory

Introduction

Pacific Northwest National Laboratory is a DOE multiprogram laboratory located in Richland, Washington that supports DOE's science, national security, energy, and homeland security missions. PNNL operates the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)—a 200,000 sq. ft. national scientific user facility constructed by DOE that houses 373 people. PNNL also utilizes 29 Federal facilities in the 300 Area of the Hanford Reservation (700,000 sq. ft. of space that house nearly 1,000 people). These facilities provide nearly 50% of the PNNL's laboratory space and 100% of its nuclear and radiological facilities. In addition, PNNL operates facilities on land owned by it's parent organization, Battelle Memorial Institute (494,000 sq. ft.), and leases an additional 793,000 sq. ft. of office space in the Richland area occupied by 2,330 staff.

Basic Energy Sciences

PNNL supports research in interfacial and surface chemistry, inorganic molecular clusters, analytical chemistry, and applications of theoretical chemistry to understanding surface. Geosciences research includes theoretical and experimental studies to improve our understanding of phase change phenomena in microchannels. Also supported is research on 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.

Advanced Scientific Computing Research

PNNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. PNNL also participates in several SciDAC science application teams and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers.

Biological and Environmental Research

PNNL is home to the William R. Wiley **Environmental Molecular Sciences Laboratory (EMSL),** a national scientific user facility. PNNL operates EMSL, which provides unique ultra high field mass spectrometry and nuclear magnetic resonance spectrometry instruments, as well as a wide variety of other cutting edge analytical capabilities for use by the national research community. PNNL conducts a wide variety of research in subsurface environmental remediation science, with emphases on biogeochemistry and fate and transport of radionuclides. PNNL is participating in the National Science Foundation (NSF)/DOE Environmental Molecular Sciences Institutes at Pennsylvania State University and Stanford University. It also conducts research into new instrumentation for microscopic imaging of biological systems.

PNNL provides expertise in research on aerosol properties and processes and in field campaigns for atmospheric sampling and analysis of aerosols. PNNL also conducts climate modeling research to improve the simulations of both precipitation through representation of sub-grid orography and the effect of aerosols on climate at regional to global scales. The Atmospheric Radiation Measurement (ARM) program office is located at PNNL, as is the project manager for the ARM engineering activity; this provides invaluable logistical, technical, and scientific expertise for the program. PNNL manages the ARM Aerial Vehicles Program (AAVP) as well. PNNL also conducts research on improving methods and models for assessing the costs and benefits of climate change and of various different options for mitigating and/or adapting to such changes. PNNL, in conjunction with ANL and ORNL and six universities, plays an important role in the CSiTE consortium, focusing on the role of soil microbial processes in carbon sequestration. PNNL also conducts research on the integrated assessment of global climate change.

PNNL is one of the major national laboratory partners that comprise the JGI, the principal goal of which is high-throughput DNA sequencing. One of PNNL's roles in the JGI involves proteomics research (identifying all the proteins found in cells). 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 conducts microbial systems biology research as part of Genomics: GTL. The Chief Scientist for the Genomics: GTL program is at PNNL.

Fusion Energy Sciences

PNNL has focused on research on materials that can survive in a fusion neutron environment. 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 ferrite steels as part of the U.S. fusion materials team.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

The PNNL S&S program consists of program management, physical security systems, protection operations, information security, cyber security, personnel security and material control and accountability.

Pacific Northwest Site Office

The Pacific Northwest Site Office provides the single federal presence with responsibility for contract performance at Pacific Northwest National Laboratory. This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Princeton Plasma Physics Laboratory

Introduction

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 88.5 acres in Plainsboro, New Jersey. The laboratory consists of 36 buildings

(721,000 gross square feet of space) with an average building age of 32 years. DOE does not own the land.

Advanced Scientific Computing Research

PPPL participates in SciDAC science application teams related to fusion science.

High Energy Physics

The HEP program supports a small theoretical research effort at PPPL using unique capabilities of the laboratory in the area of advanced accelerator R&D.

Fusion Energy Sciences

PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. The laboratory 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 National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device, closely related to the tokamak, and has started construction of another innovative toroidal concept, the National Compact Stellarator Experiment (NCSX). PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks and the NSF Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas in the U.S., as well as several large tokamak facilities abroad, including JET (Europe), JT-60U (Japan), and KSTAR (Korea). 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 also has a large theory group that does research in the areas of turbulence and transport, equilibrium and stability, wave-plasma interaction, and heavy ion accelerator physics. PPPL, LBNL, and LLNL currently work together in advancing the physics of heavy ion drivers through the heavy ion beams Fusion Virtual National Laboratory. Effective July 2004, PPPL, in partnership with ORNL, was selected to manage the U.S. ITER Project Office. In January 2006, based on the management successes of the Spallation Neutron Source, ORNL was chosen as the lead laboratory to manage the U.S. Contributions to ITER, Major Item of Equipment project, with PPPL supporting them. Through its association with Princeton University, PPPL provides high quality education in fusion-related sciences, having produced more than 200 Ph.D. graduates since its founding in 1951.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

The S&S 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. The PPPL S&S program consists of protective forces, security systems, cyber security, and program management.

Princeton Site Office

The Princeton Site Office provides the single federal presence with responsibility for contract performance at the Princeton Plasma Physics Laboratory. This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Sandia National Laboratories

Introduction

Sandia National Laboratories (SNL) is a multiprogram laboratory located on 3,700 acres in Albuquerque, New Mexico (SNL/NM), with sites in Livermore, California (SNL/CA), and Tonopah, Nevada.

Basic Energy Sciences

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. It is also the site of two BES supported user facilities—the Combustion Research Facility (CRF) and the Center for Integrated Nanotechnologies (CINT).

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 is often conducted in close collaboration with applied programs. A principal effort in turbulent combustion is coordinated among the chemical physics program, and programs in Fossil Energy and Energy Efficiency and Renewable Energy.

The **Center for Integrated Nanotechnologies** provides tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT is devoted to establishing the scientific principles that govern the design, performance, and integration of nanoscale materials. Through its core facility in Albuquerque, New Mexico, and its gateways to both Sandia National Laboratories and Los Alamos National Laboratory, CINT will provide access to tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT supports five scientific thrusts that serve as synergistic building blocks for integration research: nano-bio-micro interfaces, nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and theory and simulation.

Advanced Scientific Computing Research

SNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. SNL also participates in several SciDAC science application teams, and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers.

Biological and Environmental Research

In support of BER's climate change research, SNL provides the site manager for the North Slope of Alaska ARM site who is responsible for day-to-day operations at that site. In addition, SNL conducts climate modeling research on modifying the Community Atmospheric Model (CAM) to support new dynamical cores and improve its scalability for implementation on high-system computing systems. The laboratory conducts advanced research and technology development in robotics, smart medical instruments, microelectronic fabrication of the artificial retina, and computational modeling of biological systems.

Fusion Energy Sciences

Sandia 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. It 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 located in the STAR facility at INL. 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. Sandia also works with LBNL through the Heavy Ion-Fusion Virtual National Laboratory in developing high-brightness ion source and other science issues of heavy ion beams. Sandia serves an important role in the design and analysis activities related to the ITER first wall components, including related R&D.

Savannah River National Laboratory

Introduction

The Savannah River National Laboratory (SRNL) is a multiprogram laboratory located on approximately 34 acres in Aiken, South Carolina. SRNL provides scientific and technical support for the site's missions, working in partnership with the site's operating divisions.

Biological and Environmental Research

SRNL scientists support environmental remediation sciences research program in the area of subsurface contaminant fate and transport.

Stanford Linear Accelerator Center

Introduction

The Stanford Linear Accelerator Center (SLAC) is located on 426 acres of Stanford University land in Menlo Park, California. 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 photon science and has operated the 2 mile long Stanford Linear Accelerator (Linac) since 1966. SLAC consists of 115 buildings (1.7 million gross square feet of space) with the average age of 29 years. In addition, SLAC will become the site of the world's first x-ray laser, the Linac Coherent Light Source (LCLS) in 2009, and funding for operations of the SLAC Linac is transitioning from High Energy Physics to Basic Energy Sciences, with full funding by Basic Energy Sciences starting in FY 2009. SLAC houses the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), which is an independent laboratory of Stanford University.

Basic Energy Sciences

SLAC is the home of the **Stanford Synchrotron Radiation Laboratory** and peer-reviewed research projects associated with SSRL. The facility is used by researchers from industry, government laboratories, and universities. These include astronomers, biologists, chemical engineers, chemists, electrical engineers, environmental scientists, geologists, materials scientists, and physicists. A research program is conducted 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 provided major improvements that increase the brightness of the ring for all experimental stations.

Advanced Scientific Computing Research

SLAC participates in SciDAC science application teams such as the Particle Physics Data Grid.

Biological and Environmental Research

SLAC operates nine SSRL beam lines for structural molecular 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. Beamlines at SSRL also support a growing environmental science user community.

High Energy Physics

SLAC operates the **B-factory** and its detector, BaBar, and a small program of experiments in accelerator science and technology. 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. SLAC is also working at the frontier of particle astrophysics. In 2006, SLAC completed construction of the detector for the Gamma Ray Large Array Telescope (GLAST) which will be launched into earth orbit in 2007. SLAC physicists and a user community will analyze the GLAST data till at least 2012. About 1,200 particle physicists throughout the U.S. and around the world, use SLAC for their research. The HEP program also supports physics research and technology R&D at SLAC, using unique resources of the laboratory, including engineering and detector technology, advanced accelerator technology, and computational resources.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

The S&S program focuses on reducing the risk to DOE national facilities and assets. The program consists primarily of protective forces, security systems, program management, and cyber security program elements.

Stanford Site Office

The Stanford Site Office provides the single federal presence with responsibility for contract performance at the Stanford Linear Accelerator Center. This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Thomas Jefferson National Accelerator Facility

Introduction

Thomas Jefferson National Accelerator Facility is an Office of Science laboratory (Nuclear Physics) located on 206 acres (DOE-owned) in Newport News, Virginia focused on the exploration of nuclear and nucleon structure. The laboratory consists of 64 buildings (474,000 gross square feet of space) with an average building age of 15 years, 2 state leased buildings, 23 real property trailers, and 10 other structures and facilities. The laboratory was constructed over the period FY 1987–1995.

Advanced Scientific Computing Research

TJNAF participates in SciDAC science application teams such as the Particle Physics Data Grid.

Biological and Environmental Research

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

High Energy Physics

The HEP program supports an R&D effort at TJNAF on accelerator technology, using the unique expertise of the laboratory in the area of superconducting radiofrequency systems for particle acceleration.

Nuclear Physics

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. The facility has an international user community of about 1,200 researchers. Polarized electron beams up to 5.7 GeV can be provided by CEBAF simultaneously to 3 different experimental halls. Hall A is designed for spectroscopy and few-body measurements. 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. The G0 detector, a joint NSF-DOE project in Hall C, allows a detailed mapping of the strange quark contribution to nucleon structure. Also in Hall C, a new detector, Q-weak, is being developed to measure the weak charge of the proton by a collaboration of laboratory and university groups in partnership with the NSF. TJNAF supports a group that does theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy Physics. TJNAF research and engineering staff are world experts in Superconducting Radio-Frequency (SRF) accelerator technology; their expertise is being used in the development of the 12 GeV Upgrade for CEBAF and International Linear Collider, and was utilized for the completed the Spallation Neutron Source. The 12 GeV CEBAF Upgrade is being implemented and will provide researchers with the opportunity to study quark confinement, one of the greatest mysteries of modern physics.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security

TJNAF has a guard force (protective 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, material control and accountability, and security systems.

Thomas Jefferson Site Office

The Thomas Jefferson Site Office provides the single federal presence with responsibility for contract performance at Thomas Jefferson National Accelerator Facility (TJNAF). This site office provides an on-site SC presence with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

Washington Headquarters

SC Headquarters, located in the Washington, D.C. area, supports the SC mission by funding Federal staff responsible for directing, administering, and supporting a broad spectrum of scientific disciplines. These disciplines include the HEP, NP, BES, BER, FES, ASCR, and WDTS programs. In addition, Federal staff are responsible for SC-wide management, operational policy, and technical/administrative support activities in budget and planning; information technology; infrastructure management; construction management; safeguards and security; environment, safety and health; and general administration. Funded expenses include salaries, benefits, travel, general administrative support services and technical expertise, information technology maintenance and enhancements, as well as other costs funded through interdepartmental transfers and interagency transfers.

Basic Energy Sciences

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Basic Energy Sciences			
Research			
Materials Sciences and Engineering	726,895	1,004,212	1,093,219
Chemical Sciences, Geosciences, and Energy Biosciences	206,961	268,499	283,956
Total, Research	933,856	1,272,711	1,377,175
Construction	176,292	148,269	121,322
Total, Basic Energy Sciences	1,110,148[a]	1,420,980	1,498,497
Stanford Linear Accelerator Center (SLAC) Linac Operations (non-add) [b]	(29,400)	(40,000)	(61,500)
Basic Energy Sciences, excluding SLAC Linac Operations (non-add)[b]	(1,080,748)	(1,380,980)	(1,436,997)

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 108-153, "21st Century Nanotechnology Research and Development Act", 2003
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the 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 by emphasizing fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences.

Benefits

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. 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.

---

[a] Total is reduced by $11,460,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $21,794,000, which was transferred to the SBIR program; and $2,615,000, which was transferred to the STTR program.

[b] The SLAC linear accelerator (linac) supports operations of the B-Factory (funded by High Energy Physics (HEP)) and will also support operations of the Linac Coherent Light Source (currently under construction and funded by BES). With the completion of B-Factory operations in FY 2008, SC has been transitioning funding of the SLAC linac from HEP to BES, with FY 2008 representing the third and final year of joint funding with HEP. BES totals without SLAC linac funding are presented to display program growth exclusive of this functional transfer.

Basic research supported by the BES program touches virtually every aspect of energy resources, production, conversion, efficiency, and waste mitigation. Research in materials sciences and engineering leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety of energy generation, conversion, transmission, and use. For example, research on toughened ceramics results in improved high-speed cutting tools, engine turbines, and a host of other applications requiring lightweight, high-temperature materials. Research in chemistry leads to the development of advances such as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for the production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. Research in geosciences contributes to the solution of problems in multiple DOE mission areas, including reactive fluid flow studies to understand contaminant remediation and seismic imaging for reservoir definition. Finally, research in the molecular and biochemical nature of photosynthesis aids the development of solar photo-energy conversion and biomass conversion. History has taught us that seeking answers to fundamental questions results in a diverse array of practical applications as well as some remarkable revolutionary advances.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The BES program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

The BES program has one GPRA Unit Program goal which contributes to Strategic Goal 3.1 and 3.2 in the "goal cascade:"

GPRA Unit Program Goal 3.1/2.50.00: Advance the Basic Science for Energy Independence – Provide the scientific knowledge and tools to achieve energy independence, securing U.S. leadership and essential breakthroughs in basic energy sciences.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

Within the Basic Energy Sciences program, the Materials Science and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram contribute to Strategic Goals 3.1 and 3.2 by producing seminal advances in the core disciplines of the basic energy sciences—materials sciences and engineering, chemistry, geosciences, and energy biosciences. These subprograms build leading research programs that provide world-class, peer-reviewed research results cognizant of both DOE mission needs and new scientific opportunities. Scientific discoveries at the frontiers of these disciplines impact energy resources, production, conversion, efficiency, and the mitigation of the adverse impacts of energy production and use—discoveries that will accelerate progress toward energy independence, economic growth, and a sustainable environment.

The following indicators establish specific long-term (ten-year) goals in scientific advancement that the BES program is committed to and against which progress can be measured.

- Design, model, fabricate, characterize, analyze, assemble, and use a variety of new materials and structures, including metals, alloys, ceramics, polymers, biomaterials and more—particularly at the nanoscale—for energy-related applications.
- Understand, model, and control chemical reactivity and energy transfer processes in the gas phase, in solutions, at interfaces, and on surfaces for energy-related applications, employing lessons from inorganic and biological systems.
- Develop new concepts and improve existing methods to assure a secure energy future, e.g., for solar energy conversion and for other energy sources.
- Conceive, design, fabricate, and use new scientific instruments to characterize and ultimately control materials, especially instruments for x-ray, neutron, and electron beam scattering and for use with high magnetic and electric fields.

The Materials Science and Engineering subprogram also contributes to Strategic Goals 3.1 and 3.2 by managing BES facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. The synchrotron radiation light sources, neutron scattering facilities, and electron-beam microcharacterization centers reveal the atomic details of metals and alloys; glasses and ceramics; semiconductors and superconductors; polymers and biomaterials; proteins and enzymes; catalysts, molecular sieves, and filters; and materials under extremes of temperature, pressure, strain, and stress. Researchers are now able to make new materials and study their atomic formation as it happens using these new probes. Once the province of specialists, mostly physicists, these facilities are now used by thousands of researchers annually from all disciplines. The Materials Science and Engineering subprogram has established a suite of Nanoscale Science Research Centers that are changing the way materials research is done by providing the ability to fabricate complex structures using chemical, biological, and other synthesis techniques; characterize them; assemble them; and integrate them into devices—and do it all in one place. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram contributes to this goal by managing the Combustion Research Facility at Sandia National Laboratories in Livermore, California, an internationally recognized facility for advanced characterization techniques and for the study of combustion science and technology.

Funding by Strategic and GPRA Unit Program Goal

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.50.00 Advance the Basic Science for Energy Independence			
Basic Energy Sciences	1,110,148	1,420,980	1,498,497

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 3.1/2.50.00 (Advance the Basic Science for Energy Independence)					
Materials Sciences and Engineering					
N/A	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 100 nm and in the soft x-ray region was measured at 19 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 90 nm and in the soft x-ray region was measured at 15 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 90 nm and in the soft x-ray region was measured at 15 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Maintain spatial resolutions for imaging in the hard x-ray region of <100 nm and in the soft x-ray region of <18 nm, and spatial information limit for an electron microscope of 0.08 nm.[a]	Maintain spatial resolutions for imaging in the hard x-ray region of <100 nm and in the soft x-ray region of <18 nm, and spatial information limit for an electron microscope of 0.08 nm.[a]
N/A	Improve temporal resolution: X-ray pulses were measured at 20 femtoseconds in duration with an intensity of 10,000 photons per pulse. [Met Goal]	Improve temporal resolution: X-ray pulses were measured at 70 femtoseconds in duration with an intensity of 100 million photons per pulse. [Met Goal]	Improve temporal resolution: X-ray pulses were measured at 70 femtoseconds in duration with an intensity of 100 million photons per pulse. [Met Goal]	Maintain x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse (>10^8 photons/pulse).[a]	Maintain x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse (>10^8 photons/pulse).[a]
Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time. [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 91.9%). [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 97.7%). [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 96.7%). [Met Goal]	Maintain and operate the scientific user facilities to achieve an average at least 90% of the total scheduled operating time.	Maintain and operate the scientific user facilities to achieve an average at least 90% of the total scheduled operating time.
Chemical Sciences, Geosciences, and Energy Biosciences					
N/A	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a two-dimensional combustion reacting flow simulation was performed involving 44 reacting species and 518,400 grid points. [Met Goal]	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a three-dimensional combustion reacting flow simulation was performed involving 11 reacting species and 0.5 billion grid points. [Met Goal]	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a three-dimensional combustion reacting flow simulation was performed involving 33 reacting species and 21.2 million grid points. [Met Goal]	Improve Simulation: Beginning in FY 2007, increasing the size of the simulation will no longer provide useful new information. Thus, this measure is discontinued.	

[a] No further improvement is expected in FY 2007 and FY 2008 for these measures since the current suite of instruments has met their maximum performance level. This target is a measure of SC's intent to maintain the maximum level of performance for users of the current SC facilities until the next generation of instruments and facilities becomes available.

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
Construction					
Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year. [Met Goal]	Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: +1.3% cost variance and +0.8% schedule variance). [Met Goal]	Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: +0.2% cost variance and -2.5% schedule variance). [Met Goal]	Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: -1.7% cost variance and -3.2% schedule variance). [Met Goal]	Meet the cost and timetables within 10% of the baselines given in the construction project datasheets for all ongoing construction projects.	Meet the cost and timetables within 10% of the baselines given in the construction project datasheets for all ongoing construction projects.

Means and Strategies

The Basic Energy Sciences program will use various means and strategies to achieve its GPRA Unit Program goals. However, various external factors may impact the ability to achieve these goals.

The BES program will support fundamental, innovative, peer-reviewed research to create new knowledge in areas important to the BES mission, i.e., in materials sciences and engineering, chemical sciences, geosciences, and biosciences. BES also plays a critical role in constructing and operating a wide array of scientific user facilities for the nation's researchers. All research projects undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar process for the laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

External factors, in addition to budgetary constraints, that affect the level of performance include: (1) changing mission needs as described by the DOE and SC mission statements and strategic plans; (2) scientific opportunities as determined, in part, by scientific workshops and proposals received by researchers; (3) the results of external program reviews and international benchmarking activities of entire fields or sub-fields, such as those performed by the National Academy of Sciences; (4) unanticipated failures in critical components of scientific user facilities or major research programs; and (5) strategic and programmatic decisions made by non-DOE funded domestic research activities and by major international research centers.

The BES program in fundamental science is coordinated with the activities of other programs within the Office of Science and with other federal agencies (e.g., National Science Foundation, National Aeronautics and Space Administration, Department of Agriculture, Department of Interior, and National Institutes of Health). BES also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, nuclear energy, reduced environmental impacts of energy production and use, national security, and future energy sources.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Monthly, quarterly, semiannual, and annual reviews consistent with specific program management plans are performed to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department has implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government’s portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The BES program has incorporated feedback from OMB into the FY 2008 Budget Request and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the BES program a score of 93% overall, which corresponds to a rating of “Effective.” OMB found the program to be strategically driven and well managed. Outside expert panels have validated the program’s merit-based review processes ensuring that research supported is relevant and of very high quality. The assessment also found that BES has developed a limited number of adequate performance measures, which are continued for FY 2008. These measures have been incorporated into this Budget Request, BES grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain our scientific performance measures, the Office of Science developed a website (http://www.sc.doe.gov/measures) that answers questions such as “What does this measure mean?” and “Why is it important?” Roadmaps, developed in consultation with the Basic Energy Sciences Advisory Committee (BESAC), will guide triennial reviews by BESAC of progress toward achieving the long term Performance Measures. These roadmaps are posted on the SC website. The Annual Performance Targets are tracked through the Department’s Joule system and reported in the Department’s Annual Performance and Accountability Report.

OMB has previously provided BES with three recommendations to further improve performance:

- Follow up on recommendations of past expert reviews and use new reviews to assess progress toward long-term programmatic goals.
- Improve performance reporting at BES user facilities to better reflect the instrumentation and staffing issues most directly connected to scientific output.
- Produce a plan for managing and operating the High Flux Isotope Reactor (HFIR) that explicitly addresses the reliability problems while ensuring public health and safety.

In response to OMB’s past recommendations BES has:

- Continued to use an external assessment process to review its funding management practices and the quality, relevance, and performance of the research that it funds. The most recent review found the Materials Sciences and Engineering Division to be well managed and supporting a research portfolio with excellent national and international standing.
- Formally charged BESAC to assess progress toward the long term goals of the BES program as part of the regular BESAC Committee of Visitors reviews of BES program areas.
- Established new measures to assess effective utilization of its major user facilities and continued efforts to improve performance reporting of its facilities.
- Conducted two peer reviews of the HFIR in May 2006. The first addressed progress toward the completion and installation of the cold source. The second addressed the operations of the reactor and the scientific program. The second review also examined issues of reliability. Both reviews considered the facility in the context of the larger neutron scattering program at the Oak Ridge National Laboratory (ORNL). A report summarizing the results of HFIR reviews and actions to correct operational deficiencies was provided to OMB by DOE on September 21, 2006.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov web site. Information concerning BES PART assessments and current follow up actions can be found by searching on “basic energy sciences” at http://ExpectMore.gov.

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 a research effort 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 Acts of 1992 and 2005.

Today, the BES program is one of the nation's largest sponsors of research in the natural sciences. It 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 2006, the program funded research in more than 175 academic institutions located in 47 states and in 13 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; for characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological samples; and for studying the chemical transformation of materials. 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, more than 10,000 researchers from universities, national laboratories, and industrial laboratories will perform experiments at these facilities in the coming years. 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 2001 "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 miniaturized batteries;
- 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 and/or 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; and
- processes for extraction of radioactive and hazardous metal ions from solutions for nuclear fuel purification/reprocessing and for cleanup of radioactive wastes.

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 understanding comes in large measure from synchrotron x-ray and neutron scattering sources, electron microscopes, and other atomic probes as well as terascale computers. The BES program has played a major role in enabling the nanoscale 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.

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), intra-DOE and 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 BES works are given in the sections below.

Advisory and Consultative Activities

Charges are provided to BESAC by the Under Secretary for Science, who also serves as 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 performance measurement; 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, biomolecular materials, and computational modeling at the nanoscale; on the fundamental research challenges posed by the Department's energy missions; on a 20-year roadmap for BES facilities; and on theory and computation needs across the entire portfolio of BES research. Of particular note is the BESAC report, "Basic Research Needs to Assure a Secure Energy Future," which describes 10 themes and 37 specific research directions for increased emphasis. This report will help the program map its research activities for many years to come.

Information and reports for all of the above mentioned advisory and consultative activities are available on the BESAC website (http://www.science.doe.gov/bes/BESAC/BESAC.htm). 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 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). 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 reviews. The outcomes of these reviews helped develop new models of operation for existing light sources and neutron scattering facilities as well as the new Spallation Neutron Source, which was completed in FY 2006.

Facilities that are in design or construction are reviewed according to procedures set down in DOE Order 413.3A "Program and Project Management for Capital Assets" and in the Office of Science "Independent Review Handbook" (http://www.science.doe.gov/opa/PDF/revhndbk.pdf). In general, once a project has entered the construction phase (e.g., the Linac Coherent Light Source), it is reviewed with external, independent committees approximately 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:

- Scientific and/or technical merit or the educational benefits of the project;
- Appropriateness of the proposed method or approach;
- Competency of personnel and adequacy of proposed resources;
- Reasonableness and appropriateness of the proposed budget; and
- 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 reviews the major elements of the BES program using Committees of Visitors (COVs). COVs are charged with assessing the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document proposal actions; the quality of the resulting portfolio, specifically the breadth and depth of portfolio elements and the national and international standing of the elements; and progress toward the long-term PART goals. The first three reviews assessed the chemistry activities (FY 2002), the materials sciences and engineering activities (FY 2003), and the activities associated with the management of the light sources, the neutron sources, and the new Nanoscale Science Research Centers (FY 2004). This COV review cycle began again in FY 2005, so that all elements of the BES program are reviewed 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 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 the following: 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; increased investments for ultrafast science to probe processes that happen on the timescale of chemical reactions; and increases for targeted program areas for which both scientific opportunity and mission need are high (e.g., basic research for the hydrogen economy, basic research for effective solar energy utilization, and basic research for nuclear fuel cycles) 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, the Linac Coherent Light Source, the Nanoscale Science Research Centers, or upgrades or replacements to existing facilities such as the High Flux Isotope Reactor, the Stanford Synchrotron Radiation Laboratory, and the National Synchrotron Light Source-II follow from input from BESAC and from broad, national strategies that include the input from multiple federal agencies.

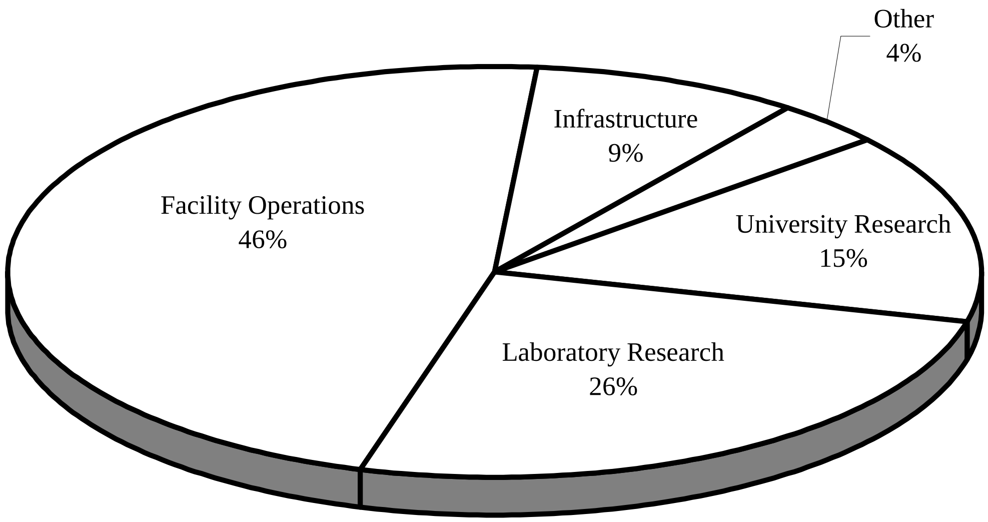
The FY 2008 budget request continues priorities established in the past few years. The Spallation Neutron Source enters its second year of full operation after construction from FY 1999 to FY 2006. A significant investment in the area of nanoscale science includes the operation of new Nanoscale Science Research Centers at Oak Ridge National Laboratory (ORNL), Lawrence Berkeley National Laboratory (LBNL), Argonne National Laboratory (ANL) and Sandia National Laboratories (SNL)/Los Alamos National Laboratory (LANL), and Brookhaven National Laboratory (BNL). Construction funding is provided for the Linac Coherent Light Source (LCLS), a fourth generation light source that will provide orders of magnitude higher intensities of coherent x-ray light than do current synchrotron radiation light sources. The LCLS will be a facility for groundbreaking research in the physical and life sciences owing to its femtosecond pulses of extremely high peak brightness x-ray beams. It will be the first such facility in the world. R&D funding is provided for upgrades on next-generation x-ray synchrotron sources. Project Engineering Design and R&D funding are provided for the National Synchrotron Light Source-II (NSLS-II) project, which sets a new standard for storage-ring-based light sources. The NSLS-II would be the first light source that combines nanometer spatial resolution with high brightness, coherence, and beam stability, thus enabling routine nanometer-scale characterization of materials. Construction funding is provided for the User Support Building at the Advanced Light Source to provide laboratory and instrument set-up space for the users of the light source.

Finally, funding is provided to renovate a two-story wing of the Central Laboratory building at the Stanford Linear Accelerator Center (SLAC) for a new research initiative—the Photon Ultrafast Laser Science and Engineering (PULSE) Center. The PULSE Center, together with LCLS, the Stanford Synchrotron Radiation Laboratory, and research programs in materials and chemical sciences, create a robust and diverse photon sciences research program at SLAC.

How We Spend Our Budget

The BES program has three major program elements: research, facility operations, and construction and laboratory infrastructure support. Of that part of the program that supports research, approximately one-third goes to support work in universities, with most of the remainder going to support work in DOE laboratories. 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. Project Engineering Design (PED) and construction funding remain significant budget components in FY 2008 for the Linac Coherent Light Source, the National Synchrotron Light Source-II, and the Advanced Light Source User Support Building.

Basic Energy Sciences Budget Allocation
FY 2008



Research

The BES program is one of the nation's largest supporters of fundamental research. 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 is 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, large teams of closely collaborating researchers, or a large technical support staff 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.

Collaborations between National Laboratory Research and University Research: Historically, collaborations between the two research sectors have been strong, particularly in areas where both sectors derive significant benefits. Examples include the use of the major BES facilities by university and industry researchers and the contribution of these researchers to new instrument concepts and to instrument fabrication at the facilities. The Nanoscale Science Research Centers and new activities in ultrafast science and basic research for the hydrogen economy are expected to both strengthen and broaden these partnerships.

Significant Program Shifts

In FY 2008, there are a number of significant program milestone increases and decreases, including the following in the area of construction, Major Items of Equipment, and facility operations:

- Construction of the Spallation Neutron Source (SNS) was officially completed on June 5, 2006, ahead of schedule, under budget, and meeting all technical milestones. Over the next two to three years, the facility will continue to fabricate and commission instruments and will increase power to full levels. Two Major Items of Equipment will permit the fabrication of approximately nine to ten additional instruments for the SNS, thus nearly completing the initial suite of 24 instruments that can be accommodated in the high-power target station.
- All five Nanoscale Science Research Centers will be operational in FY 2008: the Center for Nanophase Materials Sciences at Oak Ridge National Laboratory, the Molecular Foundry at Lawrence Berkeley National Laboratory, the Center for Nanoscale Materials at Argonne National Laboratory, the Center for Integrated Nanotechnologies at Sandia National Laboratories and Los Alamos National Laboratory, and the Center for Functional Nanomaterials at Brookhaven National Laboratory.
- The Linac Coherent Light Source will continue construction at the planned levels. Funding is provided separately for design and fabrication of instruments for the facility. Funding is also provided to partially support operation of the Stanford Linear Accelerator Center (SLAC) linac. This marks the third year of the transition of linac funding from the High Energy Physics Program to the Basic Energy Sciences Program.
- Support is provided for PED ($45,000,000) and Other Project Costs ($20,000,000) for the National Synchrotron Light Source-II (NSLS-II), which is proposed to be built as a replacement for NSLS to enable the study of material properties and functions, particularly materials at the nanoscale, at a level of detail and precision never before possible. NSLS-II would provide the world's finest capabilities for x-ray imaging.
- Support is provided for construction of the Advanced Light Source User Support Building ($17,200,000), which will provide space for experimental setup of equipment prior to use at the Advanced Light Source, space to accommodate a long beam line that will extend from the floor of the Advanced Light Source into the User Support Building, and temporary office space and conference rooms for users.
- Support is provided for PED ($950,000) and Construction ($6,450,000) for renovation of a two-story wing of the SLAC Central Laboratory building to house offices and laser laboratories for the Photon Ultrafast Laser Science and Engineering (PULSE) Center.

In FY 2008, there are shifts in the nanoscale science and engineering research activities contributing to the BES investments in research at the nanoscale and an overall increase in funding. All five planned Nanoscale Science Research Centers are in operation. Overall, the total investment for these Nanoscale Science Research Centers increases due to cost-of-living increases in the facility operations budget. Funding for research at the nanoscale increases owing to increases in funding for activities related to the hydrogen economy and for general funding increases in research at the nanoscale. The table below provides a summary of nanoscale science research funding within BES. In addition to this funding, a new request of $3,000,000 is identified in the Biological and Environmental Research (BER) program for research relevant to environmental and ecological aspects of nanomaterials. This work will be coordinated between BER and BES.

Nanoscale Science Research Funding

	(dollars in thousands)				
	TEC	TPC	FY 2006	FY 2007	FY 2008
Materials Sciences and Engineering					
Research			67,982	108,542	122,330
Major Item of Equipment, Center for Nanophase Materials, ANL			14,000	—	—
Facility Operations					
Center for Functional Nanomaterials, BNL			—	—	19,934
Center for Integrated Nanotechnologies, SNL/A & LANL			11,500	19,190	19,934
Center for Nanophase Materials Sciences, ORNL			17,800	19,190	19,934
Center for Nanophase Materials, ANL			3,500	19,190	19,934
Molecular Foundry, LBNL			8,000	19,190	19,934
Chemical Sciences, Geosciences, and Energy Biosciences					
Research			28,769	49,109	57,085
Construction					
Center for Functional Nanomaterials, BNL	79,700	81,000	36,187	18,864	366
Center for Integrated Nanotechnologies, SNL/A & LANL	73,754	75,754	4,580	247	—
Molecular Foundry, LBNL	83,604	84,904	9,510	257	—
Total			201,828	253,779	279,451

In FY 2008, $59,500,000 is requested for basic research activities to realize the potential of a hydrogen economy. The research program is based on the BES workshop report “Basic Research Needs for the Hydrogen Economy” that can be found at http://www.science.doe.gov/production/bes/hydrogen.pdf. The 2003 report highlights the gap between our present capabilities for hydrogen production, storage, and use and those required for a competitive hydrogen economy. To be economically competitive with the present fossil fuel economy, the cost of fuel cells must be lowered by a factor of five and the cost of producing hydrogen must be lowered by a factor of four. Moreover, the performance and reliability of hydrogen technology for transportation and other uses must be improved dramatically. Simple incremental advances in the present state-of-the-art cannot bridge this gap. Narrowing the gap significantly will require a comprehensive, long-range program of innovative high-risk/high-payoff basic research that is intimately coupled to and coordinated with applied programs. The objective of such a program must not be evolutionary advances but rather revolutionary breakthroughs in understanding and in controlling the chemical and physical interactions of hydrogen with materials. Detailed findings and research directions identified during the workshop are presented in the report.

In response to the BES solicitation on Basic Research for the Hydrogen Fuel Initiative for FY 2005 funding, 668 qualified preapplications were received in five submission categories: novel materials for hydrogen storage; membranes for separation, purification, and ion transport; design of catalysts at the nanoscale; solar hydrogen production; and bio-inspired materials and processes. Three of the five focus areas—novel storage materials, membranes, and design of catalysts at the nanoscale—accounted for about 75% of the submissions. Following a review, principal investigators on about 40% of the preapplications were invited to submit full applications; 227 full applications were received and were peer reviewed according to the guidelines in 10 CFR 605; 70 awards were made in late FY 2005. BES involved staff from the Office of Energy Efficiency and Renewable Energy (EERE) in the preapplication review process to ensure basic research relevance to technology program goals. Furthermore, BES has begun participation in EERE's annual program review meeting to promote information sharing. In FY 2006, BES organized parallel sessions at that meeting for the BES principal investigators. The research topic of hydrogen storage was emphasized. A total of $21,473,000 in new funding related to the hydrogen economy was awarded in FY 2005 as a result of this solicitation. An additional $17,500,000 in FY 2007 and an additional $9,500,000 in FY 2008 will be used to fund new proposals based on new solicitations.

President's Hydrogen Initiative

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Materials Sciences and Engineering Research	15,472	28,075	33,420
Chemical Sciences, Geosciences, and Energy Biosciences	17,028	21,925	26,080
Total Hydrogen Initiative	32,500	50,000	59,500

Stanford Linear Accelerator Center, Linac Operations

For decades, SLAC has been one of the world's leading research laboratories in 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. With the advent of the Linac Coherent Light Source (LCLS) project, the role that SLAC plays in x-ray science has greatly expanded. Indeed, after the planned shutdown of the B-factory at the end of FY 2008, the SLAC linac will be dedicated to the world's first x-ray free electron laser. The potential applications of this new experimental tool are legion: nanotechnology, solid-state physics, biology, energy production, medicine, electronics, and fields that do not yet exist. Recognizing the importance of the SLAC linac to the BES program, the Office of Science has been transitioning support for the SLAC linac from HEP to BES, with FY 2008 marking the third and final year of split funding.

BES funding for SLAC Linac operations is shown on the "Linac for LCLS, SLAC" line within Materials Science and Engineering/Facilities Operations activity. The following tables identify the SLAC linac funding amounts within BES and overall.

SLAC Linac Operations Funding within BES

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Materials Science and Engineering/Facility Operations			
Linac for LCLS, SLAC	29,400	40,000	61,500
Other BES Facility Operations	423,733	604,885	637,024
Total, Materials Science and Engineering/Facility Operations	453,133	644,885	698,524

Total SLAC Linac Operations Funding

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Basic Energy Sciences	29,400	40,000	61,500
High Energy Physics	56,100	52,100	32,500
Total, SLAC Linac Operations	85,500	92,100	94,000

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all Office of Science mission areas with the goal of achieving breakthrough scientific advances via computer simulation that were impossible using theoretical or laboratory studies alone. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit terascale computing and networking resources.

The SciDAC program in BES consists of two activities: (1) characterizing chemically reacting flows as exemplified by combustion and (2) achieving scalability in the first-principles calculation of molecular properties, including chemical reaction rates. In the characterization of chemically reacting flows, the scientific problem is one of multiple scales from the molecular scale (where the physical descriptions are discrete in nature) to the laboratory scale (where the physical descriptions are continuous). A collaboration involving Sandia National Laboratories and four universities successfully implemented a fully parallel direct numerical simulation that incorporated a widely used program for solving the species profiles for combustion systems involving dozens of species and hundreds of reactions. In achieving scalability in the first-principles calculation of molecular properties, progress has been made on several fronts, but perhaps the most encouraging is work dealing with electron correlation, a problem responsible for the poor scaling of quantum chemistry codes. A novel method for incorporating correlation directly into quantum mechanical descriptions of atoms and molecules is now being incorporated into a massively parallel computer code.

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. 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 cost and schedule variance. 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 percentages. 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.

Synchrotron Light Source and Neutron Scattering Facility Operations

	FY 2006 Actual	FY 2007 Estimate	FY 2008 Estimate
All Facilities			
Optimal Hours[a]	31,300	32,700	32,700
Scheduled Hours[b]	29,595	32,700	32,700
Unscheduled Downtime	11.5%	<10%	<10%
Number of Users	9,211	9,660	10,020
Advanced Light Source			
Optimal Hours[a]	5,600	5,600	5,600
Scheduled Hours[b]	6,109[c]	5,600	5,600
Unscheduled Downtime	2.5%	<10%	<10%
Number of Users	2,158	2,100	2,200
Advanced Photon Source			
Optimal Hours[a]	5,000	5,000	5,000
Scheduled Hours[b]	4,876	5,000	5,000
Unscheduled Downtime	2.5%	<10%	<10%
Number of Users	3,274	3,300	3,500
National Synchrotron Light Source			
Optimal Hours[a]	5,400	5,400	5,400
Scheduled Hours[b]	5,880[d]	5,400	5,400
Unscheduled Downtime	4.2%	<10%	<10%
Number of Users	2,105	2,300	2,300

[a] Optimal hours represent the total number of hours the facilities can operate for users, which excludes routine maintenance, machine research, operator training, accelerator physics, etc. In addition, scheduled upgrades and known shutdowns for the specified fiscal year are taken into consideration. A difference between optimal hours and scheduled hours reflects a reduction in operating hours due to funding limitations.
[b] Scheduled hours for FY 2006 represent the actual number of hours delivered to users
[c] Actual hours exceed optimal hours in FY 2006 because planned downtime for maintenance and upgrades was deferred into FY 2007. FY 2007 actual hours will reflect the downtime for upgrades.
[d] Hours delivered to users exceeded optimal hours because maintenance downtime was less than expected due to a low number of faults and no major installations in FY 2006.

	FY 2006 Actual	FY 2007 Estimate	FY 2008 Estimate
Stanford Synchrotron Radiation Laboratory			
Optimal Hours[a]	5,000	5,000	5,000
Scheduled Hours[b]	4,821	5,000	5,000
Unscheduled Downtime	3.8%	<10%	<10%
Number of Users	1,124	1,200	1,300
High Flux Isotope Reactor			
Optimal Hours[a]	2,400	4,500	4,500
Scheduled Hours[b]	556	4,500	4,500
Unscheduled Downtime	89.5%	<10%	<10%
Number of Users	42	220	220
Intense Pulsed Neutron Source			
Optimal Hours[a]	3,600	3,600	3,600
Scheduled Hours[b]	3,575	3,600	3,600
Unscheduled Downtime	3.2%	<10%	<10%
Number of Users	211	240	200
Manuel Lujan, Jr. Neutron Scattering Center			
Optimal Hours[a]	4,300	3,600	3,600
Scheduled Hours[b]	3,778	3,600	3,600
Unscheduled Downtime	16.8%	<10%	<10%
Number of Users	297	300	300
Spallation Neutron Source[c]			

Cost and Schedule Variance

	FY 2006 Actual	FY 2007 Estimate	FY 2008 Estimate
Spallation Neutron Source, ORNL			
Cost Variance	+1.25%		
Schedule Variance	-0.35%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Ring Beam Available to Target	N/A	N/A
	Approve Critical Decision 4 – Start of Operations		

[a] Optimal hours represent the total number of hours the facilities can operate for users, which excludes routine maintenance, machine research, operator training, accelerator physics, etc. In addition, scheduled upgrades and known shutdowns for the specified fiscal year are taken into consideration. A difference between optimal hours and scheduled hours reflects a reduction in operating hours due to funding limitations.
[b] Scheduled hours for FY 2006 represent the actual number of hours delivered to users.
[c] For the Spallation Neutron Source, there is an inadequate basis for making a reliable estimate at this time.

	FY 2006 Actual	FY 2007 Estimate	FY 2008 Estimate
Linac Coherent Light Source, SLAC			
Cost Variance	-4.03%		
Schedule Variance	-2.72%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 3b – Start Construction	None	None
Center for Nanophase Materials Sciences, ORNL			
Cost Variance	+0.01%		
Schedule Variance	-1.03%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 4b – Start Full Operations	N/A	N/A
Center for Integrated Nanotechnologies, SNL/LANL			
Cost Variance	+0.72%		
Schedule Variance	-0.61%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 4a – Start Initial Operations	Approve Critical Decision 4b – Start of Full Operations	N/A
The Molecular Foundry, LBNL			
Cost Variance	-0.24%		
Schedule Variance	-0.87%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 4a – Start of Initial Operations	Approve Critical Decision 4b – Start of Full Operations	N/A
Center for Nanoscale Materials, ANL			
Cost Variance	+2.01%		
Schedule Variance	-4.26%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 4a – Start of Initial Operations	Approve Critical Decision 4b – Start of Full Operations	N/A
Center for Functional Nanomaterials, BNL			
Cost Variance	-2.97%		
Schedule Variance	-8.64%		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	Approve Critical Decision 4a – Start of Initial Operations	Approve Critical Decision 4b – Start of Full Operations

	FY 2006 Actual	FY 2007 Estimate	FY 2008 Estimate
Instrumentation for Spallation Neutron Source I, ORNL			
Cost Variance	+1.35%		
Schedule Variance	-2.21%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 2 for Instruments #4-5 – Performance Baseline Approve Critical Decision 3 for Instrument #3 – Start Construction Approve Critical Decision 3 for Instruments #4-5 – Start Construction	none	Approve Critical Decision 4 – Start of Operations for Instruments #1-2
Transmission Electron Aberration Corrected Microscopy (TEAM), LBNL			
Cost Variance	[a]		
Schedule Variance	[a]		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 1 – Alternative Selection/Cost Range	Approve Critical Decision 2 – Performance Baseline Approve Critical Decision 3 – Start of Construction	Approve Critical Decision 4a – Start of Operation TEAM 0.5
Advanced Light Source User Support Building, LBNL			
Cost Variance	[a]		
Schedule Variance	[a]		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	Approve Critical Decision 1 – Alternative Selection/Cost Range Approve Critical Decision 2 – Performance Baseline Approve Critical Decision 3 – Start of Construction	None

Construction and Infrastructure

- **Linac Coherent Light Source (LCLS) Project**

  Most x-ray experiments performed at synchrotron radiation light sources produce static pictures of materials averaged over relatively long times. However, the electrons and atoms in molecules, crystal lattices, polymers, biomaterials, and all other materials are in constant motion. Merely

[a] Performance Baseline approved 1st Quarter, FY 2007.

measuring atomic "form" will not tell us all there is to know about molecular "function." We need to perform experiments that provide us with information on the motions of atoms in materials as well as their equilibrium positions. This will give us insight as never before possible into catalysis, chemical processes, protein folding, and molecular assembly.

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 and that has pulse lengths measured in femtoseconds—the timescale of electronic and atomic motions. The 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 even more 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 (Angstrom) range. The characteristics of the light from the LCLS will open new realms of scientific inquiry and 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. Optical devices beyond the undulator manipulate the direction, size, energy, and duration of the x-ray beam and carry it to whatever experiment is under way. The availability of the SLAC linac for the LCLS Project creates a unique opportunity (worldwide) for demonstration and use of x-ray FEL radiation.

FY 2008 budget authority of $51,356,000 is requested. The estimated Total Project Cost is $379,000,000. Additional information on the LCLS Project is provided in the LCLS construction project datasheet, project number 05-R-320.

- **National Synchrotron Light Source – II (NSLS-II) Project**

The NSLS-II is a proposed new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It would also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these would enable the study of material properties and functions with a spatial resolution of one nanometer (nm), an energy resolution of 0.1 millielectron volt (meV), and the ultra-high sensitivity required to perform spectroscopy on a single atom.

The NSLS-II would have the best storage-ring-based synchrotron light source in the world, but, more importantly, the NSLS-II would be transformational in that it can open new regimes of scientific discovery and investigation. The ability to probe materials with 1 nm or better spatial resolution and to analyze their dynamics with 0.1 meV energy resolution will be truly revolutionary. For example, it should be possible to investigate the atomic and electronic structure and chemical composition of nanometer-scale objects under realistic in-situ device operating conditions. It should also be possible to investigate processes that change the energy or spin state of electrons, such as their interaction with the atomic lattice or other electrons or spins. These processes form the foundation of many diverse phenomena, such as photosynthesis and spin-based quantum computing, and the ability to study them with high spatial resolution would be unprecedented.

In FY 2008, budget authority is requested to continue Project Engineering and Design ($45,000,000) and for R&D activities ($20,000,000) to address technical risks in four key areas—energy resolution, spatial resolution, superconducting undulators, and superconducting storage ring magnets. These R&D activities will be carried out at Brookhaven National Laboratory and by researchers elsewhere as needed. Additional information on the NSLS-II Project is provided in the NSLS-II Project Engineering and Design datasheet, project number 07-SC-06.

- **Advanced Light Source (ALS) User Support Building Project**

  The ALS User Support Building to be located at the Lawrence Berkeley National Laboratory will provide high-quality user support space in sufficient quantity to accommodate the very rapid growth in the number of ALS users and to accommodate projected future expansion. Efficient use of the experimental beamlines at the ALS requires adjacent space for setting up experimental apparatus before moving the apparatus into place on the experimental floor. By the end of FY 2005, almost 40 beamlines were in simultaneous and nearly continuous operation for the use of 2,000 scientists and students. All available floor space for staging experiments is now occupied with operating beamlines, necessitating shutdown of beamlines and work stoppage when the experimental apparatus is built, when it is commissioned, and when it is moved into place at the beamline. Such use of beam time is unacceptable for advanced, state-of-the art instrumentation. In addition to being too small, the current user support space does not meet seismic building codes. Structural upgrades have been evaluated and would not be cost effective. The User Support Building will provide staging areas for ALS experiments, space for a long beamline that will extend from the floor of the ALS into the User Support Building, and temporary office space for visiting users. FY 2008 budget authority of $17,200,000 is requested for construction using a design-build approach that is based on private sector best practices. Additional information on the ALS User Support Building Project is provided in the User Support Building datasheet, project number 08-SC-01.

- **Photon Ultrafast Science and Engineering (PULSE) Center**

  The PULSE Center is a new research activity at SLAC that builds on existing SLAC core competencies in the atomic physics, chemistry, condensed matter physics, and biology. The PULSE Center will focus on ultrafast structural and electronic dynamics in materials sciences, the generation of attosecond laser pulses, single-molecule imaging, and the origin of efficient light harvesting and solar energy conversion in molecular systems.

  The PULSE Center will be located in the Central Laboratory building (B040), a mixed use building consisting of three joined structures: a three-story wing joined to a two-story wing by a one story section. Approximately 18,000 square feet of existing space in the two-story wing of the Central Laboratory building will be renovated to meet the new PULSE program needs. Roughly 33% of the space will be used for offices, 50% for lab space, and 17% for conference/meeting rooms. In FY 2008, budget authority is requested to initiate Project Engineering and Design ($950,000) and construction renovation ($6,450,000) activities. Additional information is provided in the Photon Ultrafast Laser Science and Engineering Building Renovation datasheet, project number 08-SC-11.

General Plant Projects (GPP) and General Purpose Equipment (GPE)

BES provides funding for GPP and 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 doctoral degrees, 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 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 education and experience in fundamental research. 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 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.

	FY 2006	FY 2007 estimate	FY 2008 estimate
# University Grants	810	1,000	1,080
Average Size	$150,000	$150,000	$150,000
# Permanent Ph.D.s (FTEs)	3,900	4,830	5,220
# Postdoctoral Associates (FTEs)	1,140	1,380	1,480
# Graduate Students (FTEs)	1,810	2,170	2,350

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007, the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Materials Sciences and Engineering

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Materials Sciences and Engineering			
Materials Sciences and Engineering Research	273,762	335,099	368,398
Facilities Operations	453,133	644,885	698,524
SBIR/STTR	—	24,228	26,297
Total, Materials Sciences and Engineering	726,895	1,004,212	1,093,219

Description

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 and the Nanoscale Science Research Centers.

Included within the $368,398,000 research component of this subprogram for FY 2008 are facility-related activities such as R&D for new and upgraded facilities, accelerator and detector research, and all BES FY 2008 Major Items of Equipment. These activities total $56,211,000.

Benefits

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.

Supporting Information

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, electron beam microcharacterization, nanotechnology, and new instrumentation. This subprogram, a premier sponsor of condensed matter and materials physics in the U.S., is the primary supporter of the BES user facilities.

Selected FY 2006 Research Accomplishments

- *Nanofluidic transistor*. Imagine a valve to precisely control the flow of liquids but with dimensions so tiny that only one molecule at a time can pass through it. Controlled flow of ions in a liquid was recently demonstrated through very small nanochannels barely large enough to pass large molecules. Named “nanofluidic transistors,” the nanochannel assembly functions in a way similar to ordinary transistors where the flow of electrons can be regulated by applying a voltage. Demonstrations were carried out on a 35-nanometer channel constructed between two silicon dioxide plates; the channel was filled with water and potassium chloride salt. The flow of potassium ions could be completely stopped by applying an electric current across the channel. The regulation of the flow (or current) of charged molecules was also demonstrated. This exciting discovery now makes possible detection and separation of individual molecules in a fluid. Among the important implications of this discovery are advanced nanoscale chemical analysis with extreme sensitivity and the capability of sorting individual molecules.
- *Unexpected spontaneous reversal of magnetization in nanoscaled structures*. New and unexpected magnetic phenomena have been discovered in ultrathin bilayers of ferromagnetic and antiferromagnetic films. Ferromagnetic materials (e.g., iron) have a positive magnetization due to the alignment of the magnetic moments. Antiferromagnet materials (e.g., nickel oxide) have no net magnetization due to the anti-parallel alignment of the magnetic moments. In bulk magnetic materials, regions of aligned magnetic moments, termed magnetic domains, are expected to align with an external applied magnetic field. The magnetic strength is determined by the degree of alignment of the magnetic domains. In contrast to naturally occurring bulk magnetic materials, an ultrathin ferromagnetic layer in close contact with an antiferromagnetic layer will spontaneously align *opposite* to the applied magnetic field upon cooling. The close proximity of the two different layers also results in an increase in magnetic strength. The ability to control and detect the magnetic alignment in ultrathin magnetic materials could lead to new concepts in computer data storage design. The fundamental understanding of the unexpected phenomena may also influence future research and development of magnetic based biological and chemical sensors.
- *Nano-electronic hydrodynamics and turbulence*. Electrons moving across a nanometer-sized wire have been found to behave hydrodynamically, i.e., like a liquid flowing from one bucket to another through a small opening. This behavior is exactly contrary to expectations from a quantum mechanical prediction, and it has prompted theoretical predictions of new phenomena. Most striking is the prediction of possible turbulent electrical transport with eddy currents in nanoscale conductors that could seriously limit current flow. Such turbulent currents could then lead to extremely high electronic temperatures due to the “friction” of the electrons as they move against each other, resulting in potential premature failure at much reduced current flow. Experiments are being carried out to test these theoretical developments.
- *Using bioinspired methods to synthesize and assemble materials*. Biological systems are renowned for synthesizing inorganic materials under mild conditions and assembling them into exquisitely shaped structures with high precision and control. Recently, by emulating the underlying chemistry and approaches of biology, several inorganic materials have been synthesized under mild conditions (room temperature, neutral pH, etc.), with a potential for significant energy savings in their large-scale manufacture. Some of the materials synthesized include semiconducting titanium dioxide, gallium oxide, and zinc oxide for solar energy conversion; ferroelectric barium titanate nanoparticles for energy storage; magnetite nanoparticles for ultra-high density magnetic information storage; and nanocrystalline palladium for hydrogen storage. Furthermore, by exploiting the ability of biological

macromolecules (e.g., DNA, proteins, viruses) to self-assemble into large, well-defined structures and to nucleate the growth of inorganic materials, researchers have shown that complex electronic circuit elements and large ordered arrays of nanoparticles can be assembled with a precision that far exceeds the current top-down fabrication capabilities.

- *Unveiling the superconductor mystery*. Understanding the phenomena of superconductivity and its mechanism has been among the most challenging issues facing the condensed matter and materials physics communities. The mystery of superconductivity is being tackled by a concerted effort, coupling synthesis and characterization with theory, modeling, and simulation. The recent discovery of superconductivity in actinide- and boron-containing materials indicates superconductivity may exist in many material systems yet to be discovered. The search for new materials is augmented by sophisticated techniques to modify the electronic properties of known superconducting materials, both chemically and electrically. Advances in new characterization tools, including proximal probes, have made possible the discovery of new phenomena, including competing phases within the superconducting phase. First principles calculations assisted by generalized density functional theory enabled accurate predictions of the electronic structure of superconducting materials. When coupled to an electron pairing mechanism, numerical models are being developed to predict the superconducting transition temperature as a first step towards a priori design of new superconductors.

Selected FY 2006 Facility Accomplishments

- The Advanced Light Source (ALS) at LBNL

  Experiments begin on new femtosecond X-ray beamline. Experiments using ultrafast soft x-rays began in FY 2006 on Beamline 6.0.1.2. High-resolution x-ray spectroscopy and diffraction at photon energies from 150–1800 eV are now possible using the new, high-brightness, in-vacuum-undulator beamline, which increases the flux by a factor of 1000 relative to its predecessor. Beamline 6.0.1, a complementary hard x-ray beamline using the same insertion device and extending the photon energy available to users from 2.2–10 keV, was also installed, and its commissioning was begun. In the first measurements, soft x-ray pulses of 200-femtosecond duration were used to study phase transitions in vanadium oxide.

- The Advanced Photon Source (APS) at ANL

  Record nanofocusing with an innovative lens design. A new device, the Multilayer Laue Lens, developed at Argonne National Laboratory jointly between the APS and the Center for Nanoscale Materials, has set a world's record for line size resolution produced with a hard x-ray beam. The wafer from which the device was made won a 2005 R&D 100 award, given to the world's top 100 scientific and technological innovations. Enhancements to the device have now increased its ability to focus the x-rays with an energy level of 19.5 keV to less than 20 nanometers. Using the lens, researchers will be able to visualize three-dimensional electronic circuit boards to find circuit errors, map impurities in biological or environmental samples at the nanometer scale, or analyze samples inside high-pressure or high-temperature cells because hard x-rays, unlike soft x-rays, are able to penetrate container walls. This device has potential for a multitude of uses, including possible incorporation at the nanoprobe beamline at APS associated with the Center for Nanoscale Materials facility.

- The National Synchrotron Light Source (NSLS) at BNL

  Novel undulator design developed and installed. A custom-designed, cryogenic-ready, in-vacuum, miniature-gap hybrid undulator has been installed in the X25 straight section of the NSLS x-ray ring. The new radiation source, the first of its kind, will be an order of magnitude brighter than the original wiggler. By cooling the magnet array, this insertion device can have a higher magnetic field and a higher radiation resistance, resulting in a larger photon energy tuning range. Consequently, unlike previous miniature-gap undulators in use at the NSLS, this new undulator will be continuously tunable from 2 to 20 keV by employing all harmonics up through the 9th. This upgrade will provide significant benefits to the macromolecular crystallography program at the NSLS. This technology will be useful to all medium-energy storage rings in the world.

- The Stanford Synchrotron Radiation Laboratory (SSRL) at SLAC

  Operation at high current of 500 mA. The SPEAR3 accelerator reached its design current of 500 mA for the first time during a special run last year. Under similar test conditions, a selected beam line (BL 6) was subsequently operated successfully at 500 mA to test the performance of newly designed optical components, including the liquid-nitrogen-cooled double crystal monochromator. The success of this test paves the way for commissioning the other beam lines. The SPEAR3 accelerator received permission to operate routinely at 500 mA following an extensive accelerator readiness review. Authorization for operating beam lines for users at 500 mA is expected during the FY 2007 user run, when selected time periods will be allocated to commission, characterize, and operate beam lines at high current. SSRL is planning to operate full time with high current in FY 2008.

- The Spallation Neutron Source (SNS) at ORNL

  Commissioning and initial instrument results. Construction and commissioning of the Spallation Neutron Source, an accelerator-based neutron source that will provide the most intense pulsed neutron beams in the world for scientific research and industrial development, was completed, and the facility began operations in late FY 2006. The backscattering spectrometer that is part of the initial suite of instruments has unprecedented dynamic range and an energy resolution of better than 3×10^{-6} electron volts. Initial operation of this hardware involved test measurements of excitations in picoline (a hydrocarbon), which confirmed the performance of the instrument.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Materials Sciences and Engineering Research	**273,762**	**335,099**	**368,398**
▪ **Structure and Composition of Materials**	**19,385**	**22,245**	**24,245**

This activity supports basic research on the structure and composition of materials including research on the arrangement and identity of atoms and molecules in materials and the development of quantitative characterization techniques, theories, and models describing how atoms and molecules are arranged. Also sought are the mechanisms by which the arrangements are created and evolve. Increasingly important are the structure and composition of inhomogeneities including defects and the morphology of interfaces, surfaces, and precipitates.

The properties of materials used in all areas of energy technology depend upon their structure. Performance improvements for environmentally acceptable energy generation, transmission, storage, and conversion technologies likewise depend upon the structural characteristics of advanced materials. This dependence occurs because the spatial and chemical inhomogeneities in materials (e.g., dislocations, grain boundaries, magnetic domain walls, and precipitates) determine and control critical behaviors such as fracture toughness, ease of fabrication by deformation processing, charge transport and storage capacity, surface/catalytic reactivity, superconducting parameters, magnetic behavior, corrosion susceptibility, etc.

Capital equipment is provided for items such as new electron microscopes and improvements to existing instruments.

In FY 2008, funding will continue on 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. Within this funding, there is an increase to support new research to develop ultrafast electron scattering probes as companion tools to ultrafast photon probes ($+2,000,000). The main emphasis will be on characterization of transient nonequilibrium nanoscale structures.

	FY 2006	FY 2007	FY 2008
▪ **Mechanical Behavior and Radiation Effects**	**11,766**	**18,195**	**20,195**

This activity supports basic research to understand the deformation, embrittlement, fracture, and radiation damage of materials. Work supported includes the behavior of materials under repeated or cyclic stress, under high rates of stress application as in impact loading, and over a range of temperatures corresponding to the stress and temperature conditions in energy conversion systems. The objective is to achieve an atomic-level understanding of the relationship between mechanical behavior and defects in materials, including defect formation, growth, migration, and propagation. This research aims to build on this atomic-level understanding to develop predictive models for the design of materials having superior mechanical behavior. The focus of basic research in radiation effects is to achieve an atomic-level fundamental understanding of mechanisms of radiation damage and to learn how to design radiation-tolerant materials. Concerns include radiation induced embrittlement and radiation assisted stress-corrosion cracking. Other goals include achieving an atomic level understanding of amorphization mechanisms (transition from crystalline to a non-crystalline phase) and the modification of surface behavior by techniques such 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 mechanical properties of materials and aspects of nuclear technologies ranging from radioactive waste storage to extending the lifetime of nuclear facilities.

Capital equipment is provided for items such as in-situ high-temperature furnaces and characterization instrumentation.

In FY 2008, funding will continue support for research on understanding the mechanisms that are related to both the deformation and degradation of materials. Specific emphasis will be on nanoscale mechanics, and in particular the complex mechanical interactions of fundamental building blocks in directed self assembly. The program also supports the development of new theoretical and experimental tools to probe the deformation and degradation behaviors at the nanoscale. Within this funding, there is an increase to enhance core research activities in high temperature mechanical behavior and radiation effects in materials under extreme environments ($+2,000,000).

	FY 2006	FY 2007	FY 2008
▪ **Physical Behavior of Materials**	**23,298**	**29,756**	**34,193**

This activity supports basic research at the atomic and molecular level to understand, predict, and control physical behavior and functional properties of materials by developing models for the response of materials to environmental stimuli such as temperature, electromagnetic fields, chemical environments, 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; and diffusion and transport of ions in ceramic electrolytes for improved performance in batteries and fuel cells.

Research underpins the missions 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 important.

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.

In FY 2008, major activities will include basic research for solar to electricity conversion. Areas of emphasis include polycrystalline, nanocrystalline, and organic materials to replace expensive single crystals; innovative design of interpenetrating photoconversion materials networks to improve charge separation and collection efficiency; and the development of novel processes to obtain extremely high conversion efficiencies at modest cost. With the anticipated vigorous development of new types of nanoscale materials, new opportunities will emerge to dramatically improve solar energy conversion efficiency. Within this funding, there is an increase to initiate new research activities in inorganic and organic light emitting materials ($+2,000,000). Special emphasis will be on novel materials or concepts, including nanophotonics and other nanoscale material assemblies and architectures. An additional increase will fund new solar-to-electricity and solar-to-fuels conversion research ($+2,437,000).

	FY 2006	FY 2007	FY 2008
▪ **Synthesis and Processing Science**	**15,357**	**21,022**	**24,522**

This activity supports basic research to understand and develop innovative ways to make materials with desired structure, properties, or behavior. Examples of activities in synthesis and processing include the growth of single crystals of controlled orientation, purity, and perfection; the formation

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

of thin films of controlled structure and orientation by various techniques; atomic and molecular self assembly to create and explore new materials; nanostructured materials including those that mimic the structure of natural materials; the preparation and control of powder or particulate matter for consolidation into bulk form by many alternative processes; sol-gel processes; the welding and joining of materials including dissimilar materials or materials with substantial differences in their coefficients of thermal expansion; plasma, laser, and charged particle beam surface modification and materials synthesis; and myriad issues in process science. This activity also includes development of in-situ measurement techniques and capabilities to quantitatively determine variations in the energetics and kinetics of growth and formation processes on atomic or nanometer length scales.

This activity includes the operation ($727,000) of the Materials Preparation Center at the Ames Laboratory, which develops innovative and superior processes for materials preparation and provides small quantities of research-grade, controlled-purity materials and crystals that are not otherwise available to academic, governmental, and industrial research communities to be used for research purposes.

This activity underpins 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.

Capital equipment includes controlled crystal growth apparatus, furnaces, lasers, chemical vapor and molecular beam epitaxial processing equipment, plasma and ion sources, and deposition equipment.

In FY 2008, funding will include continued support for research on nanoscale synthesis and processing. Major emphasis will be on providing synthesis and processing capabilities to enable the manipulation of individual spin, charge, and atomic configurations to probe the atomistic basis of the emergent behavior. Research on emergent behavior will have a significant impact on developing new materials and devices for energy applications, including spin-based electronics and multifunctional sensors. Within this funding, there are increases to support new research activities on novel approaches to the design, discovery and synthesis of materials for hydrogen storage ($+1,500,000). Key emphasis will be on tailoring the atomic and molecular structure and chemical arrangements to maximize the storage capacity while maintaining optimal kinetic characteristics for practical charge and discharge functions. New research activities will also be initiated in the design and synthesis of nanoscale materials ($+2,000,000).

▪ **Engineering Research**	**2,006**	**1,000**	**—**

This activity supported studies of the conduction of heat in terms of the interactions of phonons (or crystal lattice vibrations) with crystalline defects and impurities and the transfer of mass and energy in turbulent flow in geometrically constrained systems and the mechanics of nanoscale systems.

In FY 2008, the remaining engineering research activities are terminated because of competing priorities.

▪ **Neutron and X-ray Scattering**	**44,313**	**62,055**	**63,355**

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

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

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 nanoscale catalysts, 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. X-ray and neutron scattering, together with the electron scattering supported under Structure and Composition of Materials and Electron-beam Microcharacterization Facilities, are the primary tools for characterizing the atomic, electronic, and magnetic structures of materials.

Research in the areas of nanostructured materials and novel hydrogen storage media will be continued using the structural and chemical information garnered from x-ray and especially neutron scattering. Structural studies on carbon-based hydrogen storage media-such as nanotubes, nanohorns, fullerenes, and nanoscale hydrides-also will be performed to reveal the site of hydrogen incorporation and the mechanisms of hydrogen storage. The knowledge and technique developed in this activity have broad applicability in developing new materials for efficient and environmentally acceptable energy technologies.

Capital equipment is provided for items such as detectors, monochromators, mirrors, and beamline instrumentation at all of the facilities.

In FY 2008, activities will be initiated in photon-based ultrafast materials science research to characterize the physical, lattice, and electronic structures of highly correlated electron systems ($+1,300,000).

▪ **Experimental Condensed Matter Physics**	**37,279**	**47,480**	**50,480**

This activity supports condensed matter physics with emphases in 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. This activity includes the design and synthesis of new materials with new and improved properties. These materials 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 are made under extreme conditions of temperature, pressure, and magnetic field.

This research is aimed at a fundamental understanding of the behavior of materials that underpin DOE technologies. This activity supports research in photovoltaics, superconductivity, magnetic materials, thermoelectrics, and optical materials that underpin various technology programs in Energy Efficiency and Renewable Energy (EERE). Research in superconductivity and photovoltaics is coordinated with the solar technologies program in EERE. In addition, this activity supports the strategically important information technology and electronics industries in the fields of semiconductor physics, electronics, and spintronics research.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Capital equipment is provided for crystal growth equipment, scanning tunneling microscopes, electron detectors for photoemission experiments, sample chambers, superconducting magnets, and computers.

In FY 2008, major activities will continue in the development of nanomaterials for both energy conversion and hydrogen energy storage, which exhibit size-dependent properties that are not seen in macroscopic solid-state materials. Enhanced electrical, thermal, mechanical, optical, and chemical properties have shown that these new nanomaterials could lead to dramatic improvements in the technologies relevant to fuel cells, batteries, capacitors, nanoelectronics, sensors, photovoltaics, thermal management, super-strong lightweight materials, hydrogen storage, and electrical power transmission. Within this funding, there is an increase to enhance key core research activities in low dimensional materials and other strongly correlated electron systems ($+3,000,000).

	FY 2006	FY 2007	FY 2008
▪ **Condensed Matter Theory**	**23,198**	**27,408**	**31,753**

This activity supports basic research in theory, modeling, and simulations of the condensed matters, and it complements the Experimental Condensed Matter Physics activity. A current major thrust is in nanoscale science, where 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, progress in establishing the theoretical framework for more complex materials and hybrid structures has been limited. 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.

The Computational Materials Sciences Network supports cooperative research teams for studies requiring numerous researchers with diverse expertise ($1,730,000). Examples include fracture mechanics—understanding ductile and brittle behavior; microstructural evolution in which microstructural effects on the mechanics of materials; magnetic materials across all length scales; excited state electronic structure and response functions; and strongly correlated electron systems. The knowledge and computational tools developed in this activity have broad applicability on programs supported by Energy Efficiency and Renewable Energy and National Nuclear Security Administration.

Capital equipment will be provided for items such as computer workstations, beamline instruments, ion implantation, and analytical instruments.

In FY 2008, major activities will include theoretical and computational approaches capable of interrogating systems to gain direct insight on the mechanisms underpinning the cooperative behavior of complex systems. Unlocking the mysteries of these systems will provide the scientific foundation for designing and engineering new multifunctional materials, devices and sensors with exquisitely sensitive properties. Within this funding, there is an increase to support new theory, modeling and simulation activities to characterize and understand key mechanisms governing the interactions of hydrogen with materials for high-capacity solid-state hydrogen storage ($+2,345,000). Major emphasis for hydrogen research will be on establishing the theoretical framework via multi-time and multi-spatial scale approaches to predict and guide the design of solid-state hydrogen storage materials for transportation and stationary applications. New activities will be initiated to understand new electron pairing mechanisms to guide the future design of bulk and nano-architectured complex oxides with strongly correlated electron behavior ($+2,000,000).

	FY 2006	FY 2007	FY 2008
▪ **Materials Chemistry**	**42,040**	**49,748**	**54,467**

This activity supports basic research on the design, synthesis, characterization, and properties of novel materials and structures. The portfolio emphasizes solid-state chemistry, surface chemistry, and interfacial chemistry. It includes investigation of novel materials such as low-dimensional solids, self-assembled monolayers, electrocatalysts, cluster and nanocrystal-based materials, conducting and electroluminescent polymers, organic superconductors and magnets, complex fluids, hybrid materials, biomolecular materials and solid-state neutron detectors. There is a continued interest in the synthesis of new complex materials with nanoscale structural control and unique material properties that originate at the nanoscale. Significant research opportunities also exist at the biology/materials science interface. A wide variety of experimental techniques are employed 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 program also supports the development of new experimental techniques such as surface force apparatus in combination with various spectroscopies.

The research in this activity underpins many energy-related technological areas such as batteries and fuel cells, catalysis, friction and lubrication, membranes, sensors and electronics, and materials aspects of environmental chemistry. The development of synthetic membranes using biological approaches may yield materials for advanced separations and energy storage.

Capital equipment is provided for such items as advanced nuclear magnetic resonance and magnetic resonance imaging instrumentation and novel atomic force microscopes.

In FY 2008, major activities will include solar-to-fuels conversion research, with an emphasis on tailoring the absorption and charge separation via the control of photon and electron motion in materials. Such activities will take full advantage of the nanotechnology/biotechnology revolutions to enable exquisite design of materials and the mimicking of natural function. The confluence of the emerging nanoscale hybrid materials and advances in the understanding of nature's design rules of its photosynthetic and catalytic systems opens up opportunities for combining biological and inorganic/organic components in engineered assemblies with unprecedented efficiencies for the conversion of solar photons to fuels and chemicals. Within this funding, there is an increase to support new research activities for developing bio-inspired approaches to solar hydrogen production and bio-mimetic catalysis for hydrogen storage and fuel cell needs ($+1,500,000). The emphasis will be on tailoring the absorption and charge separation via the control of photon and electron motion in materials and taking full advantage of the nanotechnology/biotechnology revolutions to enable exquisite design of materials and the mimicking of natural function. Additional activities will be initiated for the design and synthesis of biomolecular organic materials for electronic applications ($+2,000,000) and for new basic research for electrical energy storage ($+1,219,000).

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		

- **Experimental Program to Stimulate Competitive Research (EPSCoR)** **7,280** **8,000** **8,240**

  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, Delaware, Hawaii, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, New Hampshire, Nevada, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee (graduated from program in April 2006), Vermont, West Virginia, Wyoming, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands. The work supported by the EPSCoR program includes research in materials sciences, chemical sciences, biological and environmental sciences, high energy physics, and nuclear physics, fusion energy sciences, and the basic sciences underpinning fossil energy, energy efficiency, and renewable energy. In FY 2008, funding is increased for EPSCoR research activities ($+240,000). The following table shows EPSCoR distribution of funds by state.

EPSCoR Distribution of Funds by State

Alabama	685	258	128
Alaska	—	—	—
Arkansas	135	139	—
Delaware	—	—	—
Hawaii	—	—	—
Idaho	375	375	375
Kansas	135	—	—
Kentucky	—	—	—
Louisiana	462	375	375
Maine	—	—	—
Mississippi	132	—	—
Montana	455	133	131
Nebraska	265	269	140
Nevada	740	105	468
New Hampshire[a]	—	—	—
New Mexico	135	—	—
North Dakota	923	—	350
Oklahoma	350	350	350
Rhode Island	—	—	—
Puerto Rico	375	—	—
South Carolina	660	525	525

[a] Became eligible in FY 2006.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
South Dakota	125	—	—
Tennessee	140	140	140
Vermont	—	—	—
U.S. Virgin Islands	—	—	—
West Virginia	855	135	495
Wyoming	140	140	—
Technical Support	193	110	110
Other[a]	—	4,946	4,653

▪ **Electron-beam Microcharacterization**	**7,790**	**7,945**	**8,183**

This activity, which was previously budgeted in Structure and Composition of Materials, supports three electron-beam microcharacterization user centers: 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 centers contain a variety of highly specialized instruments to provide information on the structure, chemical composition, and properties of materials from the atomic level up, using direct imaging, diffraction, spectroscopy, and other techniques based primarily on electron scattering.

Atomic arrangements, local bonding, defects, interfaces and boundaries, chemical segregation and gradients, phase separation, and surface phenomena are all aspects of the nanoscale and atomic structure of materials, which ultimately controls the mechanical, thermal, electrical, optical, magnetic, and many other properties and behaviors. Understanding and control of materials at this level is critical to developing materials for and understanding principles of photovoltaic energy conversion, hydrogen production, storage, and utilization, catalysis, corrosion, response of materials in high-temperature, radioactive, or other extreme environments, and many other situations that have direct bearing on energy, environmental, and security issues.

Electron probes are ideal for investigating such structure because of their strong interactions with atomic nuclei and bound electrons, allowing signal collection from small numbers of atoms—or, in certain cases, just one. Furthermore, the use of these charged particles allows electromagnetic control and lensing of electron beams, resulting in spatial resolution that can approach single atomic separations or better.

Capital equipment is provided for instruments such as scanning, transmission, and scanning transmission electron microscopes, atom probes and related field ion instruments, related surface characterization apparatus and scanning probe microscopes, and auxiliary tools such as spectrometers, detectors, and advanced sample preparation equipment.

In FY 2008, additional funds are provided for continued user operations, scientific research of the staff, and development of new instruments or techniques at the electron beam microcharacterization user centers ($+238,000).

---

[a] Uncommitted funds in FY 2007 and FY 2008 will be competed among all EPSCoR states.

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
▪ **Accelerator and Detector Research**	**1,522**	**3,000**	**8,985**

This activity supports basic research in accelerator physics and x-ray and neutron detectors. Research seeks to achieve a fundamental understanding beyond the traditional accelerator science and technology to develop new concepts for synchrotron radiation and spallation neutron sources. Research includes studies of the creation and transport of ultra-high brightness electron beams to drive Self Amplified Spontaneous Emission (SASE) Free Electron Lasers (FELs) such as the LCLS. Collective electron effects such as micro-bunch instabilities from coherent synchrotron and edge radiation are key areas of interest, as they can degrade the beam brightness. In the area of neutron science, there is research to develop improved high-intensity, low-emittance proton sources to achieve high-power spallation sources. More efficient proton sources can increase the reliability and lifetime due to lower radiofrequency (RF) power requirements.

This work is closely aligned and coordinated with activities in the High Energy Physics, Nuclear Physics, and Advanced Scientific Computing Research programs within the Office of Science. Coordination with other agencies, notably NSF, will continue in areas such as R&D on energy-recovery linacs and on the development of x-ray detectors. To exploit fully the fluxes delivered by synchrotron radiation facilities and the SNS, new detectors capable of acquiring data several orders of magnitude faster than present detectors are required. Improved detectors are especially important in the study of multi-length scale systems such as protein-membrane interactions as well as nucleation and crystallization in nanophase materials. They will also enable real-time kinetic studies and studies of weak scattering samples.

Capital equipment provided for these studies includes lasers for photoionization and laser wake field studies, RF hardware, data acquisition equipment, and optical equipment such as polarizers and beam splitters, interferometers, and specialized cameras.

In FY 2008, activities in novel accelerator and source concepts as well as detector research will continue. An increase is provided to continue the growth of this activity ($+5,985,000). This activity recognizes the importance of fundamental research in accelerator and detector science to the Basic Energy Sciences Program, which now supports the largest collection of synchrotron light sources and neutron scattering facilities of any organization worldwide.

▪ **General Plant Projects (GPP)**	**1,250**	**737**	**737**

GPP funding is provided for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems as part of the BES stewardship responsibilities. 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. The total estimated cost of each GPP project will not exceed $5,000,000.

▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	**2,000**	**—**	**—**

Capital Equipment funding for new and upgraded instrumentation has been completed.

▪ **Nanoscale Science Research Centers**	**993**	**500**	**500**

Funding is provided for Other Project Costs for Nanoscale Science Research Centers.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **The Center for Nanoscale Materials**	**14,000**	**—**	**—**

Funding was completed in FY 2006 for the Major Item of Equipment, with a total estimated cost of $36,000,000, for instrumentation for the Center for Nanoscale Materials at Argonne National Laboratory. The instrumentation will be contained in a new building, which was constructed by the State of Illinois at a cost of $36,000,000 and that is dedicated to the Center operations. The building is 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 permit nondestructive examination of magnetic, electronic, and photonic materials important both for basic science and as foundations for future nanotechnologies.

▪ **Spallation Neutron Source Instrumentation I**	**12,579**	**10,500**	**11,856**

Funds are provided to continue a Major Item of Equipment with a total estimated cost and total project cost of $68,500,000 for five instruments for the Spallation Neutron Source. The instrument concepts for the Major Item of Equipment project were competitively selected using a peer review process, and the instruments will be installed at the SNS on a phased schedule between FY 2007–2011. An additional Major Item of Equipment, SING II, will fund four additional instruments at the SNS.

▪ **Spallation Neutron Source Instrumentation II**	**—**	**10,000**	**10,000**

Funds are provided for a Major Item of Equipment with a Total Project Cost in the range of $40,000,000 to $60,000,000 for four instruments for the Spallation Neutron Source that will be installed at the SNS. The instrument concepts for the Major Item of Equipment project will be competitively selected using a peer review process. The project will be managed by Oak Ridge National Laboratory. The TEC range will be narrowed to a cost and schedule performance baseline following completion of Title I design and External Independent Reviews. It is anticipated that these instruments will be installed at the SNS on a phased schedule beginning in about FY 2010.

▪ **Research on Instrumentation for the Linac Coherent Light Source (LCLS)**	**1,500**	**—**	**—**

Funding was completed in FY 2006 for research leading to Critical Decision 0 for a Major Item of Equipment for instruments for the Linac Coherent Light Source.

▪ **Linac Coherent Light Source Ultrafast Science Instruments (LUSI)**	**—**	**10,000**	**10,000**

Funds are provided for a Major Item of Equipment with a total estimated cost in the range of $50,000,000 to $60,000,000 and a total project cost in the range of $54,000,000 to $64,000,000 for four instruments for the Linac Coherent Light Source that will be installed after the LCLS line item project is completed in FY 2009. These instruments, together with the instrument contained within the LCLS project, address all but one of the science thrust areas in the LCLS First Experiments report. The technical concepts for the four instruments have been developed in consultation with the scientific community through a series of workshops, conferences, and focused review committees. Instrument designs for the Major Item of Equipment project will be competitively selected using a peer review process. The project will be managed by the Stanford Linear Accelerator Center. The TEC will be narrowed to a cost and schedule performance baseline following completion of Title I

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

design and External Independent Reviews. It is anticipated that these four instruments will be installed at the LCLS on a phased schedule between FY 2009–2012. When completed, the LCLS will provide accommodations for six instrument stations, four of which will be used by the instruments in this Major Item of Equipment.

	FY 2006	FY 2007	FY 2008
▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	**6,206**	**5,508**	**6,687**

Funds are provided for a Major Item of Equipment with a total estimated cost of $11,600,000 and a total project cost of $27,087,000. The funding amounts displayed include equipment funding and other project costs which are a significant portion of the total project cost. Equipment funding included is $2,000,000 in FY 2006, $3,500,000 in FY 2007, and $6,100,000 in FY 2008. The TEAM project will construct an aberration-corrected electron microscope and make this capability available to the materials and nanoscience communities. The projected improvement in spatial resolution, contrast, sensitivity, and the flexibility of design of electron optical instruments will provide unprecedented opportunities to observe directly the atomic-scale order, electronic structure, and dynamics of individual nanoscale structures. The TEAM instrument will serve as a platform for future aberration-corrected instruments optimized for different purposes, such as wide-gap in-situ experimentation, ultimate spectroscopy, ultrafast high-resolution imaging, synthesis, field-free high resolution magnetic imaging, diffraction and spectroscopy, and other extremes of temporal, spectral, spatial or environmental conditions.

	FY 2006	FY 2007	FY 2008
Facilities Operations	**453,133**	**644,885**	**698,524**

The operations of the scientific user facilities are funded at a level that will permit service to users at the FY 2007 level or better. Studies conducted by BES in FY 2004 and FY 2005 for the synchrotron light sources concluded that the number and quality of instruments and the level of staff employed to serve the user community were not entirely adequate to provide the perceived optimal utilization of these facilities. These studies will be discussed in greater detail in the forthcoming 2007 Office of Science and Technology Policy Interagency Working Group Report on U.S. Synchrotron Radiation Light Sources. This Interagency Working Group was tasked with investigating the status, needs, associated policy matters, and interagency coordination issues required for maximizing the scientific impact and efficient operation of existing sources. The investigations included aspects of planning, development, operations, and termination of such facilities and related programs, as well as potential research needs for development of next-generation sources. In FY 2008, additional funds will be applied to these needs at all of the synchrotron light sources. In addition, funds are provided to partially support operation of the SLAC linac previously fully funded by the High Energy Physics (HEP) program. This marks the third year of a transition of support for SLAC linac operations from HEP to BES. FY 2008 funding is requested for National Synchrotron Light Source-II Other Project Costs for R&D activities to reduce technical risk, including equipment funds for instrumentation required to test prototype components. The Combustion Research Facility is funded in the Chemical Sciences, Geosciences, and Energy Biosciences subprogram at a level that will permit service to users at about the FY 2007 level. The facility operations budget request, presented in a consolidated manner later in this budget, includes operating funds, capital equipment, and accelerator and reactor improvement project (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

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

(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. Of the total operations budget, $608,332,000 goes to operating expenses, $62,315,000 to capital equipment, $26,451,000 to AIP, and $1,426,000 to GPP. The four operating Nanoscale Science Research Centers will have been peer reviewed by early 2007, so the FY 2008 budget is the last one that will show equal operations allocations. Execution of the FY 2008 budget will take into account the review results.

Facilities

	FY 2006	FY 2007	FY 2008
Advanced Light Source, LBNL	41,853	49,802	53,152
Advanced Photon Source, ANL	95,640	108,604	115,908
National Synchrotron Light Source, BNL	36,196	40,763	43,505
National Synchrotron Light Source-II	1,900	25,000	20,000
Stanford Synchrotron Radiation Laboratory, SLAC	25,925	35,836	38,413
High Flux Isotope Reactor, ORNL	57,418	51,598	54,598
Intense Pulsed Neutron Source, ANL	15,500	18,531	18,531
Manuel Lujan, Jr. Neutron Scattering Center, LANL	10,000	10,582	10,992
Spallation Neutron Source, ORNL	95,001	171,409	166,755
Center for Nanophase Materials Sciences, ORNL	17,800	19,190	19,934
Center for Integrated Nanotechnologies, SNL/LANL	11,500	19,190	19,934
Molecular Foundry, LBNL	8,000	19,190	19,934
Center for Nanoscale Materials, ANL	3,500	19,190	19,934
Center for Functional Nanomaterials, BNL	—	—	19,934
Linac Coherent Light Source (LCLS), SLAC	3,500	16,000	15,500
Linac for LCLS, SLAC	29,400	40,000	61,500

SBIR/STTR	**—**	**24,228**	**26,297**

In FY 2006, $16,914,000 and $2,030,000 were transferred to the SBIR and STTR programs, respectively. The FY 2007 and FY 2008 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

Total, Materials Sciences and Engineering	**726,895**	**1,004,212**	**1,093,219**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Materials Sciences and Engineering Research	
▪ **Structure and Composition of Materials**	
Increases are provided to support new research to develop electron scattering probes as companion tools to ultrafast photon probes.	+2,000
▪ **Mechanical Behavior and Radiation Effects**	
Increase is provided to enhance core research activities in high-temperature mechanical behavior and radiation effects in materials under extreme environments.	+2,000
▪ **Physical Behavior of Materials**	
Increase is provided for new research activities in inorganic and organic light emitting materials ($+2,000,000) and in new solar-to-electricity and solar-to-fuels conversion research ($+2,437,000).	+4,437
▪ **Synthesis and Processing Science**	
Increases are provided to support research activities on novel approaches to the design, discovery and synthesis of materials for hydrogen storage ($+1,500,000) and for the design and synthesis of nanoscale materials ($+2,000,000).	+3,500
▪ **Engineering Research**	
Activities are terminated.	-1,000
▪ **Neutron and X-ray Scattering**	
Increase is provided for research in photon-based ultrafast materials science to characterize physical, lattice and electronic structures of highly correlated electron systems.	+1,300
▪ **Experimental Condensed Matter Physics**	
Increase is provided to enhance key core research activities and other strongly correlated electron systems.	+3,000
▪ **Condensed Matter Theory**	
Increases are provided to support new theory, modeling and simulation activities to characterize and understand key mechanisms governing the interactions of hydrogen with materials for high capacity solid-state hydrogen storage ($+2,345,000) and to understand new electron pairing mechanisms to guide the future design of bulk and nano-architectured complex oxides with strongly correlated electron behavior ($+2,000,000).	+4,345

	FY 2008 vs. FY 2007 ($000)
▪ **Materials Chemistry**	
Increases are to support new research activities for developing bio-inspired approaches to solar hydrogen production and bio-mimetic catalysis for hydrogen storage and fuel cell needs ($+1,500,000), for the design and synthesis of biomolecular organic electronic materials ($+2,000,000), and for basic research for electrical energy storage ($+1,219,000).	+4,719
▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**	
Increase is provided for additional EPSCoR research activities.	+240
▪ **Electron-beam Microcharacterization**	
Increase is provided for continued user operations and development of new instruments and techniques.	+238
▪ **Accelerator and Detector Research**	
Increase is provided to continue the growth of this activity to support the next generation of accelerator-based facilities including energy recovery linacs.	+5,985
▪ **Spallation Neutron Source Instrumentation I**	
Scheduled increase for the Major Item of Equipment for instrumentation for the Spallation Neutron Source.	+1,356
▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	
Scheduled increase for the Major Item of Equipment for the Transmission Electron Aberration Corrected Microscope.	+1,179
Total, Materials Sciences and Engineering Research	**+33,299**
Facilities Operations	
▪ **Operation of National User Facilities**	
Increase for the Advanced Light Source to support accelerator operations and users above the FY 2007 level.	+3,350
Increase for Advanced Photon Source to support accelerator operations and users above the FY 2007 level.	+7,304
Increase for National Synchrotron Light Source to support accelerator operations and users above the FY2007 level.	+2,742
Decrease for National Synchrotron Light Source-II – Other Project Costs per FY 2007 project datasheet.	-5,000

	FY 2008 vs. FY 2007 ($000)
Increase for the Stanford Synchrotron Radiation Laboratory to support accelerator operations and users above the FY 2007 level and for Other Project Costs associated with the Photon Ultrafast Laser Science and Engineering (PULSE) Building Renovation ($100,000).	+2,577
Increase for High Flux Isotope Reactor to support reactor operations.	+3,000
Increase for the Manuel Lujan, Jr., Neutron Scattering Center to support target operations and users at the FY 2007 level.	+410
Decrease for Spallation Neutron Source. The decrease includes an overall increase for operations and a decrease reflecting the funding ($-8,000,000) for the one-time purchase of heavy water in FY 2007.	-4,654
Increase for the Center for Nanophase Materials Sciences for continued operations.	+744
Increase for Center for Integrated Nanotechnologies for continued operations.	+744
Increase for Molecular Foundry for continued operations.	+744
Increase for Center for Nanoscale Materials for continued operations.	+744
Increase for Center for Functional Nanomaterials to begin first year of operation.	+19,934
Decrease for Linac Coherent Light Source Other Project Costs per FY 2007 project datasheet.	-500
Increase for Stanford Linear Accelerator Center in support of the linac operations.	+21,500
Total, Facilities Operations	**+53,639**
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in total operating expense.	+2,069
Total Funding Change, Materials Sciences and Engineering	**+89,007**

Chemical Sciences, Geosciences, and Energy Biosciences

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Chemical Sciences, Geosciences, and Energy Biosciences			
Chemical Sciences, Geosciences, and Energy Biosciences Research	200,710	255,113	269,876
Facilities Operations	6,251	6,805	7,069
SBIR/STTR	—	6,581	7,011
Total, Chemical Sciences, Geosciences, and Energy Biosciences	206,961	268,499	283,956

Description

This subprogram provides support 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.

Included within the $269,876,000 research component of this subprogram is support for General Plant Projects and General Purpose Equipment totaling $15,790,000.

Benefits

Ultimately, research in chemical sciences 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. Research in geosciences 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. Research in biosciences provides the foundation for new biological, biomimetic, and bioinspired paths to solar energy conversion; fuels and chemical feedstock production; chemical catalysis; and materials synthesis.

Supporting Information

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. 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. In the area of biosciences, 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 is the nation's sole support for heavy-element chemistry, and it is the nation's primary support for homogeneous and heterogeneous catalysis, photochemistry, radiation chemistry, separations and analysis, and gas-phase chemical dynamics.

Selected FY 2006 Research Accomplishments

- *Measuring the ultrafast motion within a molecule using its own electrons*. Modern ultrafast lasers make it possible, in principle, to follow in real time the motions of the atoms that comprise a molecule. However, optical lasers are only indirect probes of atomic motion. This problem will be alleviated with the advent of the world's first x-ray free-electron laser, the Linac Coherent Light Source (LCLS), since x-rays allow direct tracking of atomic positions. Until the LCLS is available, optical laser pulses can be used in clever ways to track atomic motion in molecules. In one recently demonstrated example, the molecule's own electrons are used as the probe of atomic motion in a highly excited molecule. The electric field from an intense, optical laser pulse initially pulls electrons away from the molecule and then accelerates them back toward it. The highly energetic electrons scatter from the molecule. Rather than measure the scattered electrons, as might be done in an electron diffraction experiment, the new method exploits another phenomenon that is particularly sensitive to atomic motion. When the electrons re-collide with the molecule, they emit x-ray radiation in a process known as high-harmonic generation (HHG), and it is these x-rays that are detected. The wavelength of the re-colliding electrons is comparable to distances between atoms in a molecule; thus, the HHG x-rays emitted are highly sensitive to atomic motion within the molecule. This new method shows great promise as a way of imaging energetic molecules undergoing ultrafast structural transformations, including the fundamental action of all of chemistry, and the making and breaking of chemical bonds.
- *Sunlight-driven transformation of carbon dioxide into methanol*. The first step in the chemical transformation of carbon dioxide into a transportable fuel such as methanol involves the interaction of light with a catalyst in a process known as photocatalysis. It has long been known that the photocatalytic formation of methanol from carbon dioxide can be initiated by high-energy ultraviolet radiation. Recent work has demonstrated that the critical first reaction that splits carbon dioxide into carbon monoxide and a free oxygen atom can also be triggered with visible light. This advance makes it feasible to consider harnessing sunlight to drive the photocatalytic production of methanol from carbon dioxide. The key to the new advance is to perform the initial photocatalytic reaction on the walls of the nanometer-sized channels of a porous silica solid through the excitation by visible light of a bimetallic catalyst. The energy from the absorption of light causes an electron to transfer from one metal in the catalyst to the other and subsequently activates the gaseous carbon dioxide to eliminate an oxygen atom to yield the carbon monoxide product. Various combinations of metals are now being explored with the goal of designing a complete and sustainable system to produce methanol.
- *Catalytic synthesis of alternative fuels and chemicals*. Current manufacturing technologies for fuels and chemicals are often inefficient. The need to dramatically improve efficiency in fuel and chemical production is motivating the search for new chemical pathways using new catalysts tailored to guide chemical reactions with precision toward a selected product without wasteful sub-products. Recent approaches enlist different catalysts to cooperate in parallel to transform molecular intermediates. Sometimes referred to as tandem catalysis, this approach can potentially yield ultrahigh selectivity. An example is the venerable Fisher-Tropsch production of diesel fuel from carbon monoxide and hydrogen. Model catalysts for this polymerization reaction are typically unselective and yield a mixture of hydrocarbons or alcohols with carbon-chain lengths varying over a wide range. For

minimum energy consumption and maximum yield, the ideal process should provide a very narrow carbon-chain range. Two recent advances may rejuvenate the Fisher-Tropsch process: the discovery of efficient metathesis catalysts, which led to the Nobel Prize in Chemistry for 2006, and the selective activation of carbon-hydrogen bonds. Two catalysts are necessary to carry out these two very different functions simultaneously on the same growing polymers. The carbon-hydrogen activation catalyst limits the yield of low-end hydrocarbons, and the metathesis polymerization catalyst simultaneously controls the high-end hydrocarbons. This can potentially lead to an ideal diesel-oil without the need for energy-intensive separations. This new tandem catalysis application is being followed intensely by researchers worldwide for its potential to revolutionize the science of alternative fuels and chemicals synthesis.

- *Carrier multiplication: a possible revolutionary step toward highly efficient solar cells*. In a normal solar cell, a single photon from the sun is converted into a single carrier of electrical current (an electron-hole pair) in a bulk crystal material called a semiconductor. This process is inherently inefficient because much of the energy of the solar photon is wasted as excess heat in the semiconductor. Recent experiments on the interaction of photons with nanocrystalline samples of semiconductors have demonstrated a remarkable effect, known as carrier multiplication, in which a single photon creates multiple charge carriers. Recent work has demonstrated that as many as seven charge carriers can be created with a single photon and that the process is universal, i.e., it occurs in all types of nanocrystalline semiconductors. These new results suggest that nanoscale confinement plays an important role in the carrier multiplication mechanism, which is now thought to be an instantaneous excitation of multiple electrons by a single photon. Critical issues must be addressed before an operational solar cell based on carrier multiplication can be created, such as separating and harvesting the charge carriers to create electrical current. However, present estimates of the conversion efficiency for a solar cell based on carrier multiplication are as high as 50 percent, which is about twice that of the best solar cell in current operation. Doubling solar cell conversion efficiency would represent a revolutionary advance in our ability to harness renewable energy from the sun.
- *Visualizing chemistry: the promise of advanced chemical imaging*. The emerging possibility of "chemical imaging" is transforming the way scientists follow the chemical transformation of molecules on surfaces, within cells, or immersed in other complex environments. Chemical imaging is the term given to a set of experimental techniques that use photon beams, electron beams, or proximal electromechanical probes to track molecules in two- or three-dimensional space and real time, while keeping track of chemical identity and even molecular structure. In the ideal limit, chemical imaging means nanometer spatial resolution, femtosecond temporal resolution, and "fingerprint" recognition of the molecular mass and structure. As a recent example, researchers are using focused laser beams (space and time information) coupled with mass spectrometry (chemical identification), to track specific metabolites in functioning cells. Multiplexing the mass information allows the simultaneous mapping of several species. Understanding the metabolic transformation of important biomolecules in cells is the first step toward influencing them in service of improved biochemical processes. Other examples include the use of chemical imaging to examine single-site catalysts as they influence reactions on surfaces and light-harvesting "antenna molecules" that are key participants in photochemical charge-transfer processes.

Detailed Program Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Chemical Sciences, Geosciences, and Energy Biosciences Research	**200,710**	**255,113**	**269,876**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**15,685**	**19,248**	**21,278**

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; development of new ultrafast optical probes; and ultracold collisions and quantum condensates.

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 microcharacterization centers, and neutron scattering facilities. Furthermore, by studying energy transfer within isolated molecules, AMO science provides the 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.

Capital equipment is provided for items including lasers and optical equipment, unique ion sources or traps, position sensitive and solid-state detectors, and control and data processing electronics.

In FY 2008, major activities will include the interactions of atoms and molecules with intense laser pulses; the development of new ultrafast optical probes and theories for the interpretation of ultrafast measurements; the use of optical fields to control quantum mechanical processes; the studies of atomic and molecular interactions at ultracold temperatures; and the creation and utilization of quantum condensates that provide strong linkages between atomic and condensed matter physics at the nanoscale. Within this funding, there are increases for nanoscale science associated with complex systems ($+1,500,000) and to maintain advances in ultrafast science ($+530,000).

▪ **Chemical Physics Research**	**30,863**	**37,813**	**41,503**

This activity supports experimental and theoretical investigations of gas phase chemistry and chemistry in the condensed phase and at interfaces. 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 in the condensed phase and at well-characterized surfaces and the reactions of metal and metal oxide clusters lead to the development of theories on the molecular origins of surface-mediated catalysis.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

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 diagnostics have been developed to characterize gas-phase processes, including high-resolution optical spectroscopy, time-resolved Fourier-transform infrared spectroscopy, picosecond laser-induced fluorescence, and ion-imaging. Other activities at the Combustion Research Facility involve BES interactions with Fossil Energy, Energy Efficiency and Renewable Energy, and industry.

This activity contributes to DOE missions, since nearly 85% 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 that 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.

Capital equipment is provided for such items as picosecond and femtosecond lasers, high-speed detectors, spectrometers, and computational resources.

In FY 2008, there will be an increased emphasis on chemical physics in the condensed phase, including the fundamental understanding of weak, non-covalent interactions and their relationship to chemical and physical properties of macroscopic systems and on electron driven chemical reactions at interfaces relevant to solar energy conversion. Within this funding, there are increases for nanoscale science associated with complex behavior in the condensed phase and at interfaces ($+1,500,000), advances in chemical imaging and ultrafast science ($+971,000), and fundamental aspects of interfacial chemistry, especially at electrode-relevant surfaces, for charge transfer reactions and electrochemical energy storage ($+1,219,000).

▪ **Photochemistry and Radiation Research**	**28,591**	**32,007**	**35,000**

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 and photocatalysis, 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 ($3,298,000), 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.

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, the nuclear fuel cycle, and medical diagnosis and radiation therapy.

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.

In FY 2008, funding 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; the use of nanoscale materials in the photocatalytic generation of hydrogen from water and other fuels from fossil feedstocks; and radiolytic processes at interfaces, radiolytic intermediates in supercritical fluids, and characterization of excited states by dual pulse radiolysis/photolysis experiments. Within this funding, there are increases for enhanced research in solar hydrogen production ($+1,000,000), solar photoelectrochemistry ($+823,000), and solar photoconversion using solid-state organic systems ($+1,170,000).

	FY 2006	FY 2007	FY 2008
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	**11,920**	**18,188**	**19,926**

This activity supports fundamental research to characterize the molecular and chemical mechanisms involved in the conversion of solar energy to chemical energy. Research supported includes the characterization of the chemical processes occurring during photosynthesis, natural catalytic mechanisms involved in the synthesis of chemical fuels, and the chemistry of carbon dioxide fixation. The approaches used include physical, chemical, biochemical, and molecular structure/function analyses. The goal is to provide strategies for the design of non-biological and hybrid processes. This activity complements that in the Biological and Environmental Research program, which focuses on developing a comparative understanding of photosynthetic biological systems and on the genomic, metabolic engineering, and synthetic biology redesign of such natural systems.

Capital equipment is provided for such items as high-speed lasers, high-speed detectors, spectrometers, and computational resources.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2008, funding will support research that focuses on understanding the constituents and molecular-level interactions within natural photosynthetic systems and the detailed molecular processes associated with the absorption of solar energy and the creation of stored chemical energy. Exploiting and mimicking components of natural solar energy conversion will enable future strategies for the bio-inspired design of new energy capture systems. Within this funding, there are increases to maintain advances in both natural and artificial photosynthesis ($+471,000) and for enhanced efforts in understanding defect tolerance and self-repair in natural photosynthetic systems ($+1,267,000).

▪ **Metabolic Regulation of Energy Production**	**16,859**	**17,601**	**18,056**

This activity supports fundamental research in the molecular processes that regulate chemical reactions important to energy conversion within cells. These studies will provide the basis for designing bioinspired, synthetic systems that achieve desired chemical transformations with high efficiency and specificity. Research supported includes the molecular characterization of key biomolecular components and special assemblies that play an important role in chemical transformations of interest in energy production, transformation, and use. This activity constitutes the fundamental understanding of complex, nanoscale biochemical catalysis.

Capital equipment is provided for such items as lasers, detectors, imaging systems, spectrometers, and computational resources.

In FY 2008, increased emphasis will be placed on understanding interactions that occur within the nanoscale range. An emerging area will be the development of new imaging tools and methods for the in situ observation at high spatial and temporal resolutions. Within this funding, there is an increase for interfacial biochemistry ($+455,000).

▪ **Catalysis and Chemical Transformation**	**37,225**	**47,459**	**50,927**

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 chlorofluorocarbons 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 have improved catalytic properties.

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 2006	FY 2007	FY 2008

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.

In FY 2008, funding 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. New strategies for the rational design of selective oxidation catalysts and catalysts for the production of hydrogen from renewable feedstocks will be explored, and the control of self assembled nanoscale catalyst structures will be studied. Innovative hybrid materials that integrate biomimetic approaches with advances in catalysis will be performed, and the nature of biologically directed mineralization that results in exquisite structural control will be studied. Basic research into the chemistry of inorganic, organic, and inorganic/organic hybrid porous materials with pores in the 1-30 nm range will be undertaken, nano-scale self-assembly of these systems will be studied, and the integration of functional catalytic properties into nanomaterials will be explored. The development of a new generation of fuel-forming catalysts is necessary for integration into both higher-order artificial photosynthetic assemblies and photoelectrochemical devices. Within this funding, there are increases for enhanced catalysis research related to hydrogen production and use ($+1,685,000), for nanoscale catalyst development ($+1,000,000), and for enhanced efforts in biocatalysis and electrocatalysis ($+783,000).

	FY 2006	FY 2007	FY 2008
▪ **Separations and Analyses**	**16,388**	**24,041**	**25,907**

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 such as chemical imaging in complex, heterogeneous environments. 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 five percent of the 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.

Capital equipment is provided for such items as computational workstations and inductively coupled plasma torch spectrometers for atomic emission determination.

In FY 2008, funding will include studies 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 of how molecules interact with pore walls, with one another, and with other molecules to effect separation between molecules. Chemical analysis research will emphasize: (1) the study of hydrogen-separation materials and processes under realistic environmental conditions, rather than in high vacuum; (2) achievement of high temporal resolution, so that changes can be monitored dynamically; and (3) applications of multiple analytical measurements made simultaneously on systems such as fuel cell membranes, which have three percolation networks (proton, electron, and gas). The optimization of the light-harvesting properties of molecules on surfaces and at interfaces requires pushing the analytical means to image these molecules with the requisite spatial and temporal resolution. Within this funding, there are increases for enhanced membrane research for hydrogen ($+1,470,000) and for increased efforts in analytical chemical imaging ($+396,000).

	FY 2006	FY 2007	FY 2008
▪ **Heavy Element Chemistry**	**9,421**	**17,128**	**17,571**

This activity supports research in actinide and fission product chemistry. Areas of interest are synthesis of actinide-containing materials; theoretical methods for, and calculation of, heavy element electronic properties, molecular structure and reactivity; aqueous and non-aqueous coordination chemistry; solution and solid-state bonding and reactivity; measurement of actinide chemical and physical properties; determination of chemical properties of the heaviest actinide and transactinide elements; and studies of the bonding 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 characterize long-lived species found in storage at DOE production sites. Knowledge of the chemical characteristics of actinide and fission-product materials under waste tank conditions is necessary to treat these complex mixtures. Accidental release of actinide and fission product materials to the environment also requires molecular bonding information to predict and mitigate their transport under environmental conditions. This activity is closely coupled to the BES separations and analysis activity.

This activity represents the nation’s only funding for basic research in the chemical and physical principles governing actinide and fission product chemistry. The program is primarily at the national laboratories because of the special licenses and facilities needed to obtain and safely handle substantial amounts of radioactive materials. However, research in heavy element chemistry is supported at universities, and collaborations between university and laboratory programs are encouraged. The education of graduate students and postdoctoral researchers is 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.

Capital equipment is provided for items used to characterize actinide materials (spectrometers, ion chambers, calorimeters, etc.) and equipment to handle the actinides safely at synchrotron light source experiments.

In FY 2008, funding will continue to 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. Such studies are essential for the optimization of nuclear fuel cycles. 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. Within this funding, there is an increase for enhanced effort in the chemistry of actinides under extreme conditions ($+443,000).

	FY 2006	FY 2007	FY 2008
▪ **Geosciences Research**	**19,897**	**22,345**	**23,918**

The Geosciences activity supports long-term basic research in geochemistry and geophysics. Geochemical research focuses on new paradigms for aqueous solution chemistry, mineral-fluid interactions, and isotopic distributions and migration in natural systems. It seeks fundamental understanding of geochemical processes and reaction rates. Geophysical research focuses on new approaches to understand subsurface physical properties of fluids, rocks, and minerals, and how to determine them from the surface. It seeks fundamental understanding of the physics of wave propagation in complex media. This activity has pioneered the application of x-ray and neutron scattering to geochemical and geophysical studies.

This activity provides the basic research in geosciences that underpins the nation's strategy for understanding and mitigating the terrestrial impacts of energy technologies. The knowledge of subsurface geochemical processes, for instance, is essential to knowing the fate and transport properties of harmful heavy elements from possible nuclear waste releases. Geophysical imaging methods, likewise, are needed to measure and monitor below-ground reservoirs of carbon dioxide resulting from future large-scale carbon sequestration schemes. Finally, an emphasis on multiscale modeling harnesses modern computational power to understand and visualize data as well as to provide predictive capabilities. This activity complements that in the Biological and Environmental Research program, which focuses on the fate, transport, and remediation of DOE-relevant contaminants in the subsurface.

Capital equipment is provided for such items as x-ray and neutron scattering end stations at the BES facilities for environmental samples, and for experimental, field, and computational capabilities.

In FY 2008, funding will continue to provide the majority of individual investigator basic research support for the federal government in areas with the greatest impact on unique DOE missions such as 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

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

quality portfolios. Within this funding, there are increases for nanoscale geochemistry ($+1,000,000) and for geochemical imaging ($+573,000).

	FY 2006	FY 2007	FY 2008
▪ **Chemical Energy and Chemical Engineering**	**3,958**	**1,817**	**—**

This activity supported research on electrochemistry, thermophysical and thermochemical properties, and physical and chemical rate processes.

In FY 2008, consolidate efforts and emphasize other priorities; the remaining research in the areas of physical properties related to process engineering, engineering approaches to electrochemical fuel cells, and aspects of advanced battery research will be transferred to other programs or eliminated.

	FY 2006	FY 2007	FY 2008
▪ **General Plant Projects (GPP)**	**7,352**	**13,408**	**11,610**

GPP funding is provided 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 BES 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 2006	FY 2007	FY 2008
▪ **General Purpose Equipment (GPE)**	**2,551**	**4,058**	**4,180**

GPE funding is provided for Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the BES stewardship responsibilities for these laboratories for GPE that supports multipurpose research. Infrastructure funding is requested to maintain, modernize, and upgrade the ORNL, ANL, and Ames sites and facilities to correct deficiencies due to aging, changing technology, and inadequate past investments.

	FY 2006	FY 2007	FY 2008
Facility Operations	**6,251**	**6,805**	**7,069**

The facility operations budget request, which includes operating funds ($6,451,000), capital equipment ($496,000), and GPP ($122,000), is described in a consolidated manner later in this budget. This subprogram funds the Combustion Research Facility. 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.

Facilities

	FY 2006	FY 2007	FY 2008
Combustion Research Facility	6,251	6,805	7,069

	FY 2006	FY 2007	FY 2008
SBIR/STTR	**—**	**6,581**	**7,011**

In FY 2006, $4,880,000 and $585,000 were transferred to the SBIR and STTR programs, respectively. The FY 2007 and FY 2008 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

	FY 2006	FY 2007	FY 2008
Total, Chemical Sciences, Geosciences, and Energy Biosciences	**206,961**	**268,499**	**283,956**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Chemical Sciences, Geosciences, and Energy Biosciences Research	
▪ **Atomic, Molecular, and Optical (AMO) Science**	
Increases are provided for nanoscale science associated with complex systems ($+1,500,000) and to maintain advances in ultrafast science ($+530,000).	+2,030
▪ **Chemical Physics Research**	
Increases are provided for nanoscale science associated with complex behavior in the condensed phase and at interfaces ($+1,500,000), chemical imaging and ultrafast science ($+971,000), and interfacial chemistry at electrode-relevant surfaces ($+1,219,000).	+3,690
▪ **Photochemistry and Radiation Research**	
Increases are provided for enhanced research in solar hydrogen production ($+1,000,000), solar photoelectrochemistry ($+823,000), and solar photoconversion using solid-state organic systems ($+1,170,000).	+2,993
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	
Increase is provided to maintain advances in both natural and artificial photosynthesis ($+471,000) and enhanced efforts in understanding defect tolerance and self-repair in natural photosynthetic systems ($+1,267,000).	+1,738
▪ **Metabolic Regulation of Energy Production**	
Increase is provided for interfacial biochemistry.	+455
▪ **Catalysis and Chemical Transformation**	
Increases are provided for enhanced catalysis research related to hydrogen production and utilization ($+1,685,000), for nanoscale catalyst development ($+1,000,000), and for enhanced efforts in biocatalysis and electrocatalysis ($+783,000).	+3,468
▪ **Separations and Analyses**	
Increases are provided for enhanced membrane research for hydrogen ($+1,470,000) and for increased efforts in analytical chemical imaging ($+396,000).	+1,866
▪ **Heavy Element Chemistry**	
Increase is provided for the chemistry of actinides under extreme conditions.	+443
▪ **Geosciences Research**	
Increases are provided for nanoscale geochemistry ($+1,000,000) and for geochemical imaging ($+573,000).	+1,573

	FY 2008 vs. FY 2007 ($000)
▪ **Chemical Energy and Chemical Engineering**	
Decrease in Chemical Energy and Chemical Engineering due to termination of program.	-1,817
▪ **General Plant Projects (GPP)**	
Decrease in general plant projects due to completion of prior year projects.	-1,798
▪ **General Purpose Equipment (GPE)**	
Small increase for GPE maintenance of equipment.	+122
Total, Chemical Sciences, Geosciences and Energy Biosciences Research	**+14,763**
Facility Operations	
Increase for the Combustion Research Facility to support operations.	+264
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in operating expenses.	+430
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences	**+15,457**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Construction			
Spallation Neutron Source, ORNL	41,327	—	—
Project Engineering and Design, Linac Coherent Light Source, SLAC	2,518	161	—
Linac Coherent Light Source, SLAC	82,170	105,740	51,356
Center for Functional Nanomaterials, BNL	36,187	18,864	366
The Molecular Foundry, LBNL	9,510	257	—
Center for Integrated Nanotechnologies, SNL/LANL	4,580	247	—
Project Engineering and Design, National Synchrotron Light Source-II	—	20,000	45,000
Project Engineering and Design, Advanced Light Source User Support Building, LBNL	—	3,000	—
Advanced Light Source User Support Building, LBNL	—	—	17,200
Project Engineering and Design, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	—	—	950
Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	—	—	6,450
Total, Construction	176,292	148,269	121,322

Description

Construction is needed to support the research in each of the subprograms in the BES program. Experiments in support of basic research require that state-of-the-art facilities be built or existing facilities be modified to meet unique research requirements. Reactors, x-ray light sources, and pulsed 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.

Benefits

The new facilities that are in design or under construction—the Linac Coherent Light Source, the Center for Functional Nanomaterials, and the National Synchrotron Light Source-II—continue the tradition of BES and SC of providing the most advanced scientific user facilities for the nation's research community in the most cost effective way. All of the BES construction projects are conceived and planned with the broad user community and, during construction, are maintained on schedule and within cost. Furthermore, the construction projects all adhere to the highest standards of safety. As described in the Benefits section for the User Facilities, these facilities will provide the nation's research community with the tools to fabricate, characterize, and develop new materials and chemical processes to advance basic and applied research across the full range of scientific and technological endeavor, including chemistry, physics, earth science, materials science, environmental science, biology, and biomedical science.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **Spallation Neutron Source (SNS), ORNL**	**41,327**	**—**	**—**

On June 5, 2006, Deputy Secretary of Energy Clay Sell formally certified the successful completion of the Spallation Neutron Source (SNS) project, located at Oak Ridge National Laboratory (ORNL). The SNS project exceeded its baseline objectives, delivering more technical performance capability than promised, one month ahead of schedule and slightly under budget. In addition, the project achieved an outstanding safety record with no lost workday injuries in over 4.2 million construction work hours.

The SNS project was executed over a period of about 10 years by a DOE multi-laboratory partnership led by the SNS Project Office at ORNL. The SNS project partnership among six DOE laboratories has taken advantage of specialized technical capabilities within the laboratories: Lawrence Berkeley National Laboratory in ion sources; Los Alamos National Laboratory in linear accelerators; Thomas Jefferson National Accelerator Facility in superconducting linear accelerators; Brookhaven National Laboratory in proton storage rings; Argonne National Laboratory in instruments; and Oak Ridge National Laboratory in targets and moderators.

The SNS will become the world's leading research facility for study of the structure and dynamics of materials using neutrons. It will operate as a user facility that will enable researchers from the United States and abroad to study the science of materials that forms the basis for new technologies in telecommunications, manufacturing, transportation, information technology, biotechnology, and health.

Briefly, the SNS facility consists of the following: (1) a Front End System, where a pulsed beam of negative hydrogen ions is produced; (2) a Linear Accelerator or Linac System, where the beam is accelerated to an energy of one billion electron volts; (3) a Ring and Transfer System, where the negative ions are converted into protons and then stored in very short, high intensity pulses and then directed onto; (4) a liquid mercury Target System onto which the protons are directed, where neutrons are generated by spallation reactions and then moderated to lower energies; (5) Instrument Systems, which receive the neutrons through beam guides and where experiments are conducted; and (6) Conventional Facilities and site infrastructure, including a Central Laboratory and Office Building. The potential exists for increasing the power and adding a second target station to the SNS.

In May 2006, the first neutrons generated at SNS were used in a spectrometer instrument to study the molecular structure of a material sample. During the months ahead, the facility's proton beam power will be steadily increased, and, by 2008, the design power level of 1.4 megawatts onto the target will be reached. At the same time, the facility's availability to scientific users will also increase to full capacity.

▪ **Project Engineering and Design, Linac Coherent Light Source, SLAC**	**2,518**	**161**	**—**

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

(dollars in thousands)		
FY 2006	FY 2007	FY 2008

to be equally dramatic. The LCLS Project would 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 to subfemtosecond levels) enabling studies of fast chemical and physical processes. The LCLS has considerable potential as a tool for groundbreaking research in the physical and life sciences. LCLS x-rays can be used to create and observe extreme conditions in matter, such as exotic excited states of atoms and warm dense plasmas, previously inaccessible to study. They can be used to directly observe changes in molecular and material structure on the natural time scales of atomic and molecular motions. LCLS x-rays offer an opportunity to image non-periodic molecular structures, such as single or small clusters of biomolecules or nanostructured materials, at atomic or near-atomic resolution. These are only a few examples of breakthrough science that will be enabled by LCLS.

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.

Funds were appropriated in FY 2006 and requested in FY 2007 for Project Engineering and Design (PED) Title I and Title II design work.

	FY 2006	FY 2007	FY 2008
▪ **Linac Coherent Light Source, SLAC**	**82,170**	**105,740**	**51,356**

Funds appropriated in FY 2005 were used to initiate long-lead procurements. Early acquisition of selected critical path items supported pivotal schedule and technical aspects of the project. These include acquisition of the 120 MeV injector linac, acquisition of the undulator modules and the

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

measurement system needed for verification of undulator performance, and acquisition of main linac magnets and radiofrequency (RF) systems required to produce electron beams meeting the stringent requirements of the LCLS free-electron laser.

Funds appropriated in FY 2006 supported the start of physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall and connecting beam transfer tunnels. In addition, the injector was completed and construction of the downstream linac and electron beam transport to the undulator hall began. Undulator module assembly was started along with construction of x-ray transport/optics/diagnostics systems.

The FY 2007 funding request continued construction of the LCLS conventional facilities including the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Far Experimental Hall. In addition, the assembly and delivery of the undulators and undulator infrastructure to SLAC's Magnetic Measurement Facility continued as did procurements for the x-ray optics, diagnostics, and end stations.

Construction funding requested in FY 2008 is for completion of most of the LCLS conventional facilities and for continued procurement and installation of the technical hardware.

Performance will be measured by meeting the cost and timetables within 10% of the baseline within the construction project datasheet. Additional information on the LCLS Project is provided in the LCLS construction datasheet, project number 05-R-320.

	FY 2006	FY 2007	FY 2008
▪ **Nanoscale Science Research Center – The Center for Functional Nanomaterials, BNL**	**36,187**	**18,864**	**366**

The Center for Functional Nanomaterials (CFN), a 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.

FY 2005 funding was appropriated for the start of construction; FY 2006 funding continued construction and equipment procurement; and FY 2007 and FY 2008 funding will complete construction of the Center for Functional Nanomaterials at Brookhaven National Laboratory. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project datasheet.

	FY 2006	FY 2007	FY 2008
▪ **Nanoscale Science Research Center – The Molecular Foundry, LBNL**	**9,510**	**257**	**—**

The Molecular Foundry, a BES Nanoscale Science Research Center, will focus its research on the interface between soft materials such as those found in living systems and hard materials such as carbon nanotubes, and the integration of these materials into complex functional assemblies. The Molecular Foundry will use existing facilities such as the ALS, the NCEM, and the National Energy Research Scientific Computing Center. The Molecular Foundry will provide laboratories for

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

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; a transmission electron microscope; fluorescence microscopes; mass spectrometers; a DNA synthesizer and sequencer; a nuclear magnetic resonance spectrometer; ultrahigh vacuum scanning-probe microscopes; photo, uv, and e-beam lithography equipment; a peptide synthesizer; advanced preparative and analytical chromatographic equipment; and cell culture facilities.

FY 2004 funding was appropriated for the start of construction, FY 2005 and FY 2006 funding continued construction and equipment procurement, and FY 2007 funding will complete construction. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project datasheet.

	FY 2006	FY 2007	FY 2008
▪ **Nanoscale Science Research Center – The Center for Integrated Nanotechnologies, SNL/LANL**	**4,580**	**247**	**—**

The Center for Integrated Nanotechnologies (CINT), a 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 (LANL) and Sandia National Laboratories. 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.

FY 2003 funding was appropriated for the start of construction, FY 2004, FY 2005, and FY 2006 funding continued construction and equipment procurement, and FY 2007 funding will complete construction for 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 datasheet.

	FY 2006	FY 2007	FY 2008
▪ **Project Engineering and Design, National Synchrotron Light Source-II (NSLS-II)**	**—**	**20,000**	**45,000**

The NSLS-II is proposed as a new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It would also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these should enable the study of material properties and functions with a spatial resolution of one nanometer (nm), an energy resolution of 0.1 millielectron volt (meV), and the ultra-high sensitivity required to perform spectroscopy on a single atom. NSLS-II would be the best storage-ring-based synchrotron light source in the world, but, more importantly, NSLS-II would be transformational in that it can open new regimes of scientific discovery and investigation.

FY 2007 funding was requested to begin Project Engineering and Design (PED) Title I and Title II design. PED funds are requested in FY 2008 to complete Title II design.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project datasheet. Additional information is provided in the construction project datasheet 07-SC-06.

▪ **Project Engineering and Design, Advanced Light Source (ALS) User Support Building, LBNL**	**—**	**3,000**	**—**

The ALS User Support Building will provide high-quality user support space in sufficient quantity to accommodate the very rapid growth in the number of ALS users and to accommodate projected future expansion. The User Support Building will provide staging areas for ALS experiments, space for a long beamline that will extend from the floor of the ALS into the User Support Building, and temporary office space for visiting users. FY 2007 funding was requested for Project Engineering and Design. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project datasheet.

▪ **Advanced Light Source (ALS) User Support Building, LBNL**	**—**	**—**	**17,200**

Funds requested in FY 2008 will be used to start civil construction of the ALS User Support Building and perform Title III engineering. This project is using the design-build model for construction, which is a private-sector best practice for this type of space.

▪ **Project Engineering and Design, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC**	**—**	**—**	**950**

The Stanford Linear Accelerator Center (SLAC) is evolving from a single purpose laboratory focused on high energy physics to a dual purpose facility shifting heavily to photon science with programs in high energy physics and particle astrophysics. This shift in mission emphasis creates the need to upgrade and improve existing office and laboratory space to support the increased level of activities in the photon science mission.

Photon Ultrafast Laser Science and Engineering (PULSE) is the new center for ultrafast science at the Stanford Linear Accelerator Center (SLAC). PULSE represents a major research activity at SLAC that is a key component of the major shift in the emphasis of the laboratory from high energy physics to a multiprogram laboratory with significant activities in photon science. PULSE builds on, and leverages existing strengths in, atomic physics, chemistry, biology, and condensed matter physics. It creates an opportunity to attract outstanding scientific talent, and it will thus help ensure that Stanford University and SLAC are at the forefront of studies of ultrafast phenomena using x-rays and electrons. The PULSE Center will be located in the Central Laboratory building (B040), a mixed use building of laboratories, offices, meeting rooms, and a library. Approximately 18,000 square feet of existing space in this building will be renovated to meet the new PULSE program needs. The project scope includes refurbishment of existing offices and four existing laboratories; conversion of space for laser laboratories; and renovation of conference room space. HVAC, electrical and lighting will be modified to meet the needs of the renovated spaces. Roughly 33% of the space will be used for offices, 50% for lab space, and 17% for conference/meeting rooms.

Funds are requested in FY 2008 for PED of the renovation. Additional information is provided in the PED (08-SC-10) and construction project (08-SC-11) datasheets.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
This project will be conducted in accordance with the project management requirements in DOE Order 413.3A and DOE Manual 413.3–1, Program and Project Management for the Acquisition of Capital Assets.			
▪ **Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC**	**—**	**—**	**6,450**
Construction funds for the Photon Ultrafast Laser Science and Engineering Building Renovation described above, are requested in FY 2008 to begin the renovations. Additional information is provided in the PED (08-SC-10) and construction project (08-SC-11) datasheets.			
This project will be conducted in accordance with the project management requirements in DOE Order 413.3A and DOE Manual 413.3–1, Program and Project Management for the Acquisition of Capital Assets.			
Total, Construction	**176,292**	**148,269**	**121,322**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
▪ **Project Engineering and Design, Linac Coherent Light Source**	
Decrease in funding for Project Engineering and Design (PED) related to design-only activities for the Linac Coherent Light Source (LCLS) at SLAC, representing completion of activities.	-161
▪ **Linac Coherent Light Source, SLAC**	
Decrease in funding to continue construction for the LCLS project, representing the scheduled ramp down of activities.	-54,384
▪ **Nanoscale Science Research Center – The Center for Functional Nanomaterials, BNL**	
Decrease in funding for construction of the Center for Functional Nanomaterials at BNL, representing the scheduled ramp down of activities.	-18,498
▪ **Nanoscale Science Research Center – The Molecular Foundry, LBNL**	
Decrease in funding for construction of the Molecular Foundry at LBNL, representing the completion of activities.	-257
▪ **Nanoscale Science Research Center – The Center for Integrated Nanotechnologies, SNL/LANL**	
Decrease in funding for construction of the Center for Integrated Nanotechnologies at SNL/LANL, representing the completion of activities.	-247

	FY 2008 vs. FY 2007 ($000)
▪ **Project Engineering and Design, National Synchrotron Light Source-II (NSLS II)**	
Increase in funding to continue Project Engineering and Design.	+25,000
▪ **Project Engineering and Design, Advanced Light Source (ALS) User Support Building, LBNL**	
Decrease in funding representing completion of Project Engineering and Design.	-3,000
▪ **Advanced Light Source (ALS) User Support Building, LBNL**	
Increase in funding for construction of the ALS User Support Building and perform Title III engineering.	+17,200
▪ **Project Engineering and Design, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC**	
Increase to begin design for renovation of SLAC Building 40 to house the PULSE center.	+950
▪ **Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC**	
Increase to begin construction for renovation of SLAC Building 40 to house the PULSE center.	+6,450
Total Funding Change, Construction	**-26,947**

Major User Facilities

Funding Schedule by Activity

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 2006	FY 2007	FY 2008
Major User Facilities			
Advanced Light Source, LBNL	41,853	49,802	53,152
Advanced Photon Source, ANL	95,640	108,604	115,908
National Synchrotron Light Source, BNL	36,196	40,763	43,505
Stanford Synchrotron Radiation Laboratory, SLAC	25,925	35,836	38,413
Spallation Neutron Source, ORNL	95,001	171,409	166,755
Intense Pulsed Neutron Source, ANL	15,500	18,531	18,531
Manuel Lujan, Jr. Neutron Scattering Center, LANL	10,000	10,582	10,992
High Flux Isotope Reactor, ORNL	57,418	51,598	54,598
Center for Nanophase Materials Sciences, ORNL	17,800	19,190	19,934
Molecular Foundry, LBNL	8,000	19,190	19,934
Center for Integrated Nanotechnologies, SNL/A & LANL	11,500	19,190	19,934
Center for Nanoscale Materials, ANL	3,500	19,190	19,934
Center for Functional Nanomaterials, BNL	—	—	19,934
Combustion Research Facility, SNL/C	6,251	6,805	7,069
Linac Coherent Light Source (LCLS), SLAC	3,500	16,000	15,500
Linac, SLAC	29,400	40,000	61,500
National Synchrotron Light Source-II	1,900	25,000	20,000
Total, Major User Facilities	459,384	651,690	705,593

Description

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.

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
General Plant Projects	11,873	15,624	13,895
Accelerator Improvement Projects	4,449	25,112	26,451
Capital Equipment	69,801	131,657	147,266
Total, Capital Operating Expenses	86,123	172,393	187,612

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unappro-priated Balances
08-SC-01 Advanced Light Source User Support Building, LBNL	30,200[a]	—	—	—	17,200	10,000
08-SC-10, PED, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	950	—	—	—	950	—
08-SC-11 Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	11,060[b]	—	—	—	6,450	3,660
07-SC-06, PED, National Synchrotron Light Source-II	75,000	—	—	20,000	45,000	10,000
07-SC-12, PED, Advanced Light Source User Support Building, LBNL	3,000	—	—	3,000	—	—
05-R-320 Linac Coherent Light Source, SLAC	315,000[c]	29,760	82,170	105,740	51,356	10,000
05-R-321 Center for Functional Nanomaterials, BNL	79,700[d]	18,317	36,187	18,864	366	—
04-R-313 The Molecular Foundry, LBNL	83,604[e]	66,622	9,510	257	—	—
03-SC-002, PED, Linac Coherent Light Source, SLAC	35,974	33,295	2,518	161	—	—

[a] Includes $3,000,000 of PED included in the 07-SC-12 PED, LBNL Advanced Light Source User Support Building datasheet.
[b] Includes $950,000 of PED included in the 08-SC-10 PED, Photon Ultrafast and Laser Science and Engineering Building Renovation, SLAC datasheet.
[c] Includes $35,974,000 of PED included in the 03-SC-002 PED, SLAC, Linac Coherent Light Source datasheet.
[d] Includes $5,966,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[e] Includes $7,215,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unappro-priated Balances
03-R-313 Center for Integrated Nanotechnologies, SNL	73,754[a]	64,768	4,580	247	—	—
99-E-334 Spallation Neutron Source, ORNL	1,192,283	1,150,956	41,327	—	—	—
Total, Construction			176,292	148,269	121,322	

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
Center for Nanoscale Materials (41NG), ANL	72,500[b]	36,000	22,000	14,000	—	—	FY 2006
Spallation Neutron Source Instrumentation I (31MK), ORNL[c]	68,500	68,500	16,165	12,579	10,500	11,856	FY 2007–FY 2011 est.
Transmission Electron Aberration Corrected Microscope (61PC), LBNL	27,087	11,600	—	2,000	3,500	6,100	FY 2009
Spallation Neutron Source Instrumentation II (71RB), ORNL[d]	40,000–60,000	40,000–60,000	—	—	10,000	10,000	TBD
Linac Coherent Light Source Instrumentation (71RA), SLAC[e]	54,000–64,000	50,000–60,000	—	—	10,000	10,000	TBD
Total, Major Items of Equipment			38,165	28,579	34,000	37,956	

[a] Includes $4,159,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[b] This includes $36,000,000 provided by the State of Illinois for construction of the building.
[c] This FY 2003 MIE includes five instruments: High-Pressure Diffractometer, High-Resolution Chopper Spectrometer, Single-Crystal Diffractometer, Disordered Materials Diffractometer, and Hybrid Polarized Beam Spectrometer.
[d] Mission Need (CD-0) was approved on October 31, 2005 with a TPC range of $40–60M. The baseline TPC will be approved at CD-2 (Approve Performance Baseline). The FY 2008 Budget Request is for engineering design only.
[e] Mission Need (CD-0) was approved on August 10, 2005 with a TPC range of $50–60M. The baseline TPC will be approved at CD-2 (Approve Performance Baseline). The FY 2008 Budget Request is for engineering design only.

Advanced Scientific Computing Research

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Advanced Scientific Computing Research			
Mathematical, Information, and Computational Sciences	228,382[a]	318,654	340,198

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 108-423, "Department of Energy High-End Computing Revitalization Act of 2004"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the Advanced Scientific Computing Research (ASCR) program is to deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy. In the past two decades, scientific computation has become a cornerstone of the Department of Energy's (DOE) strategy to ensure the security of the nation and succeed in its science, energy, environmental quality, and national security missions.

Benefits

ASCR supports DOE's mission to provide world-class scientific research capacity through peer-reviewed scientific results in mathematics, high performance computing and advanced networks, and through the application of computers capable of many trillions of operations per second (terascale computers) to advanced scientific applications. Computer-based simulation enables us to model the behavior of complex systems that are beyond the reach of our most powerful experimental probes or our most sophisticated theories. Computational modeling has greatly advanced our understanding of fundamental processes of nature, such as fluid flow and turbulence or molecular structure and reactivity. Through modeling and simulation, we can investigate the interior of stars to understand how the chemical elements were created and learn how protein machines work inside living cells, which could enable us to design microbes that address critical waste cleanup problems. We can design novel catalysts and high-efficiency engines that could expand our economy, lower pollution, and reduce our dependence on foreign oil.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The ASCR program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive

[a] Total is reduced by $2,371,000 for a rescission in accordance with P.L. 109–148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $5,627,000, which was transferred to the SBIR program; and $675,000, which was transferred to the STTR program.

U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

The ASCR program has one GPRA Unit Program goal which contributes to Strategic Goal 3.1 and 3.2 in the "goal cascade":

GPRA Unit Program Goal 3.1/2.51.00: Deliver forefront computational and networking capabilities—Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The ASCR program contributes to Strategic Goals 3.1 and 3.2 by delivering the fundamental mathematical and computer science research that enables the simulation and prediction of complex physical and biological systems, providing the advanced computing capabilities needed by researchers to take advantage of this understanding, and delivering the fundamental networking research and facilities that link scientists across the nation to the computing and experimental facilities and their colleagues to enable scientific discovery. ASCR supports fundamental research in applied mathematics, computer science, computer networks, and tools for electronic collaboration; integrates the results of these basic research efforts into tools and software that can be used by scientists in other disciplines, especially through efforts such as Scientific Discovery through Advanced Computing (SciDAC); and provides the advanced computing and network resources that enable scientists to use these tools for scientific inquiry. Applied Mathematics enables scientists to accurately model physical and natural systems, and provides the algorithms the computer requires to manipulate that representation of the world effectively, exposing the underlying structure. Computer science research provides the link between the mathematics and the actual computer systems. Finally, scientific discovery results from simulations conducted on the advanced computers themselves, including experimental computers with hardware designs optimized to enable particular types of scientific applications, and the largest computing capabilities available to the general scientific community. All of these elements are to advance the frontiers of simulation. Shrinking the distance between scientists and the resources they need is also critical to Office of Science (SC). The challenges that SC faces require teams of scientists distributed across the country, as well as the full national portfolio of experimental and computational tools. High performance networks and network research provide the capability to move the millions of gigabytes that these resources generate to the scientists' desktops.

Therefore, the ASCR program contributes to research programs across SC, as well as other elements of the Department. The following indicators establish specific long term (ten year) goals in Scientific Advancement that the ASCR program is committed to, and progress can be measured against. The Advanced Scientific Computing Advisory Committee (ASCAC) has been charged to review progress toward these long term measures and were reported to the Department in the fall 2006. The long term measures are:

- Develop multiscale mathematics, numerical algorithms, and software that enable more effective models of systems such as the earth's climate, the behavior of materials, or the behavior of living cells that involve the interaction of complex processes taking place on vastly different time and/or length scales.

- Develop, through the Genomics: GTL partnership with the Biological and Environmental Research (BER) program, the computational science capability to model a complete microbe and a simple microbial community. This capability will provide the science base to enable the development of novel clean-up technologies, bio-energy sources, and technologies for carbon sequestration.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.51.00, Deliver Forefront Computational and Networking Capabilities			
Advanced Scientific Computing Research	228,382	318,654	340,198

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 3.1/2.51.00 (Deliver Forefront Computational and Networking Capabilities)					
Mathematical, Information and Computational Sciences					
Began installation of next generation National Energy Research Scientific Computing Center (NERSC) computer, NERSC-4, that will at least double the capability available in FY 2002 to solve leading edge scientific problems. [Goal Not Met]	Maintained Procurement Baselines. Percentages within (1) original baseline cost for completed procurements of major computer systems or network services, and (2) original performance baseline versus integrated performance over the life of the contracts. [Goal Met]	Maintained Procurement Baselines. Percentages within (1) original baseline cost for completed procurements of major computer systems or network services, and (2) original performance baseline versus integrated performance over the life of the contracts. [Goal Met]			
Initiated at least 5 competitively selected interdisciplinary research teams to provide computational science and applied mathematics advances that will accelerate biological discovery in microbial systems and develop the next generation of computational tools required for nanoscale science based on peer review, in partnership with the Biological and Environmental Research (BER) and Basic Energy Sciences (BES) programs, respectively, of submitted proposals. [Goal Met]	Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. [Goal Met]	Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. [Goal Met]	Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2006—>50%. [Goal Met]	Improve Computational Science Capabilities. Average annual percentage increase in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2007—>100%	Improve Computational Science Capabilities. Average annual percentage increase in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2008—>100%
Maintained and operated facilities, including NERSC and ESnet, so the unscheduled downtime on average is less than 10% of the total scheduled operating time. [Goal Met]	Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used was accounted for by computations that required at least 1/8 of the total resource. [Goal Not Met]	Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that was accounted for by computations that require at least 1/8 of the total resource. [Goal Met]	Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that was accounted for by computations that require at least 1/8 of the total resource. FY 2006—40%. [Goal Met]	Focus usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that is accounted for by computations that require at least 1/8 of the total resource. FY 2007—40%	Focus usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that is accounted for by computations that require at least 1/8 of the total resource. FY 2008—40%

Means and Strategies

The ASCR program will use various means and strategies to achieve its goals. However, various external factors may impact the ability to achieve these goals.

ASCR will support fundamental, innovative, peer-reviewed research to create new knowledge in areas of advanced computing research that are important to DOE. In addition, ASCR will plan, fabricate, assemble, and operate premier supercomputer and networking facilities that serve researchers at national laboratories, universities, and industry, thus enabling new understanding through analysis, modeling, and simulation for complex problems, and effective integration of geographically distributed teams through national laboratories. Finally, the program will continue its role in SC-wide SciDAC initiative with BES and BER in the areas of nanotechnology and Genomics: GTL. All research projects undergo regular peer review and merit evaluation based on procedures outlined in 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) mission needs as described by the DOE and SC mission statements and strategic plans; (2) evolving scientific opportunities, which sometimes emerge in a way that revolutionizes disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or subfields, such as those performed by the National Academy of Sciences (NAS); (4) unanticipated failures, e.g., in the evaluation of new computer architectures for science, that cannot be mitigated in a timely manner; (5) strategic and programmatic decisions made by other (non-DOE) Federal agencies and by international entities; and (6) the evolution of the commercial market for high performance computing and networking hardware and software.

The fundamental research program and facilities supported by ASCR are closely coordinated with the information technology research activities of other Federal Agencies (Defense Advanced Research Projects Agency [DARPA], Environmental Protection Agency [EPA], National Aeronautics and Space Administration [NASA], National Institute of Health [NIH], National Security Agency [NSA], and National Science Foundation [NSF]) through the Networking and Information Technology Research and Development (NITRD) subcommittee of the National Science and Technology Council (NSTC), under the auspices of Office of Science and Technology Policy (OSTP). This coordination is periodically reviewed by the President’s Council of Advisors on Science and Technology (PCAST). In addition to this interagency coordination, ASCR has a number of partnerships with other programs in SC and other parts of the Department, focused on advanced application testbeds to apply the results of ASCR research. Finally, ASCR has a significant ongoing coordination effort with the National Nuclear Security Administration’s (NNSA) Advanced Scientific Computing (ASC) Campaign to ensure maximum effectiveness of both computational science research efforts.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government’s portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. ASCR has incorporated feedback from OMB into the budget request and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the ASCR program an overall rating of “Moderately Effective.” The OMB found that: the program supports a supercomputer user facility and targeted research programs in applied math, computer science, and computational application software, many of which have been historically regarded as world class and of high quality; and the program’s performance measures focus on the extent to which unique, large simulations are efficiently enabled by its software development activities and supercomputer user facilities. However, OMB was concerned that the program’s external advisory committee was underutilized. In addition, OMB found that the program supports world-class scientific user facilities, has demonstrated an improved level of interagency communication and cooperation, is in the process of drafting a long-term strategic vision, and has been very successful with a major effort in interdisciplinary software. The assessment found that ASCR has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, ASCR grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance-based contracts of Management and Operating (M&O) contractors. To better explain these complex scientific measures, SC has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as “What does this measure mean?” and “Why is it important?” Roadmaps, developed in consultation with the Advanced Scientific Computing Advisory Committee (ASCAC) and also available on the website, will guide reviews every three years by ASCAC of progress toward achieving the long-term Performance Measures. In April 2006, ASCAC was charged to conduct the first such review of progress toward the long-term measures. ASCAC reported to the Department on November 10, 2006, with ratings of good and excellent. The committee reports are available at http://www.sc.doe.gov/ascr/ascac_reports.htm. The Annual Performance Targets are tracked through the Department’s Joule system and reported in the Department’s Annual Performance Report which is available at http://www.cfo.doe.gov/progliaison/part2005.htm.

For FY 2006, there were three PART related actions for Advanced Scientific Computing Research.

- Engaging advisory panel and other outside groups in regular, thorough scientific assessments of the quality, relevance, and performance of its research portfolio and computing/network facilities.
- Engaging advisory panel and other outside groups in assessments of the program’s progress in achieving its long-term goals, and in studies that revisit the strategic priorities for the program.
- Implementing action plans for improving program management in response to past expert reviews.

In response to these previous OMB recommendations ASCR has:

- Established a Committee of Visitors (COVs) to provide outside expert validation of the program’s merit-based review processes for impact on quality, relevance, and performance. ASCR is working on an action plan to respond to the recommendations of the first two COVs, which focused on the research programs and facilities, respectively. ASCR will continue to host COVs and other panels to review the quality, relevance, and performance of the program. Another COV, focused again on the research programs, will be charged in February 2007.
- The Advanced Scientific Computing Research Advisory Committee (ASCAC) reviewed progress toward the long term PART goals of the program in 2006. ASCAC has also been charged to review the ASCR facilities, including ESnet, to evaluate performance measures and scientific accomplishments. ASCAC has also been asked to make recommendations on the networking research programs within ASCR with a view towards meeting the long-term networking needs of

SC. The networking report is expected in November 2007. ASCR published responses to the COV's findings and tracked improvements at http://www.sc.doe.gov/measures/FY06.html.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov website. Information concerning ASCR PART assessments and current follow up actions can be found by searching on "Advanced Scientific Computing Research" at http://ExpectMore.gov.

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 SC research programs—Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, and Nuclear Physics—have identified major scientific challenges that can only be addressed through advances in scientific computing. The National Academies are currently carrying out a study, which was called for in the Analytical Perspectives of the President's FY 2006 Budget Request, entitled "Toward Better Understanding the Potential Impact of High-End Capability Computing on Science and Technology" to "enable a better understanding of the potential scientific impact of high-end capability computing that identifies and categorizes important scientific questions and technology problems for which an extraordinary advancement in our understanding is difficult or impossible without leading edge scientific simulation capabilities." This study is expected to better inform decision makers about the potential impact of computational science in general and ASCR's approach in particular.

ASCR research underpins the efforts of the other programs in SC. 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. The Administration has recognized the importance of high-end computing. The High End Computing Revitalization Task Force (HECRTF) report was published and ASCR is participating in implementing the plan.

How We Work

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. 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.

Advisory and Consultative Activities

The Advanced Scientific Computing Advisory Committee (ASCAC) provides valuable, independent advice to DOE 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 (IT) 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 SC Director 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; 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 NITRD subcommittee of the NSTC. The Federal IT R&D agencies have established over a decade 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 NSTC and OSTP.

In addition, ASCR, both through ASCAC and independently, supported a number of workshops to support its planning. These include the "Federal Plan for High-End Computing, report of the High End-Computing Revitalization Task Force (HECRTF)" which is available at http://www.itrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf.

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), the Advanced Computing Research Testbeds (ACRTs), and the Leadership Computing Facilities (LCFs).

NERSC, operated by the Lawrence Berkeley National Laboratory (LBNL), annually serves about 2,500 scientists throughout the United States as SC's high performance production computing facility. These researchers work at DOE laboratories, universities, industrial laboratories, and other Federal agencies. Proposals for computer time and disk storage are subjected to peer review to evaluate the quality of science, the relevance of the proposed research to SC goals and objectives, and the readiness of the proposed application to fully utilize the computing resources being requested. ASCR conducted a formal cost and schedule review of NERSC, adapting processes used to manage construction projects, in May 2005.

The ESnet, managed and operated by the LBNL, is a high-speed network serving thousands of DOE scientists and collaborators worldwide. ESnet enables researchers at national laboratories, universities, and other institutions to communicate with each other using the leading edge collaborative capabilities, not available in the commercial world, that are needed to address some of the world's most important scientific challenges. To meet the requirements of petascale science to support DOE missions have evolved, ESnet developed a plan for a new network architecture and a partnership with Internet2, the leading provider of advanced networks to U.S. universities, to develop the next generation optical network infrastructure for U.S. science. This plan was peer reviewed by the SC Office of Project Assessment in February 2005.

In FY 2004, ASCR conducted a peer review of the Center for Computational Sciences (CCS) evaluation of the Cray X1 computer. The results from this review validated the effective results of the evaluation and its contributions to the Federal high performance computing effort. Also in FY 2004, ASCR conducted a peer reviewed competition to establish a LCF for Open Science. This competition was won by a partnership of ORNL's CCS with Argonne National Laboratory (ANL) and Pacific Northwest National Laboratory (PNNL) that located the first LCF at the CCS. In March 2005 and in March 2006, the SC Project Assessment group conducted formal Baseline validation reviews of the ORNL LCF.

In FY 2006, ASCAC was charged to review the approach to performance measurement and assessment at the ASCR computing facilities, the appropriateness and comprehensiveness of the measures, the science accomplishments and their effects on Office of Science programs, the evolution of the role of the facilities and their anticipated computational needs for the next three to five years as well as progress towards the ASCR long-term PART measures. The ASCAC report on the PART measures was delivered in November 2006 with ratings of excellent for the goal related to multiscale mathematics and good for the goal related to the partnership with BER.

Program Reviews

In past years, ASCR has reviewed its applied mathematics activity at the National Labs in phases, approximately one-third each year.

In FY 2006, ASCR conducted a peer review of the Numerical Linear Algebra, Optimization, and Predictability Analysis areas at the National Labs. These areas represent 33% of the Applied Mathematics activity. In FY 2007, ASCR plans to review the Differential Equations and Advanced Numerical Methods for High Performance Computing areas within the Applied Mathematics activity, which represents an additional third of the activity.

In FY 2006, ASCR led the SC-wide re-competition of the SciDAC portfolio, with the exception of activities in partnership with the Fusion Energy Sciences program that were initiated in FY 2005. This re-competition included both disciplinary peer review and a cross-cutting panel of peers that evaluated the comprehensiveness, compatibility and impact of the potential portfolio of projects.

Planning and Priority Setting

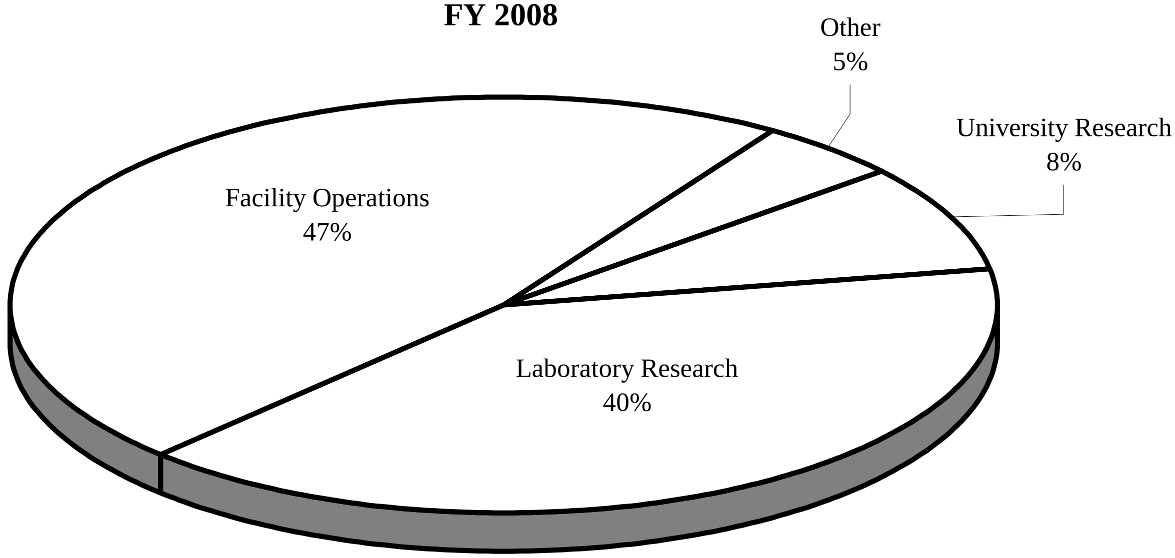
The ASCR program must coordinate and prioritize a large number of goals from agency and interagency strategic plans. One of the most important activities of ASCAC is the development of a framework for the coordinated advancement and application of network and computer science and applied mathematics. 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 SC Strategic Plan, as updated through program collaborations and joint advisory committee meetings (http://www.sc.doe.gov/Sub/Mission/mission_strategic.htm); and
- The HECRTF Plan (http://www.itrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf).

How We Spend Our Budget

The ASCR program budget has one subprogram: Mathematical, Information and Computational Sciences (MICS). The MICS subprogram has two major components: research and facility operations. The FY 2008 budget request continues the core and SciDAC research efforts and strengthens the research partnerships with other SC offices. Expenses for the operation of ESnet, which are not included in Facility Operations, account for 22% of the national laboratory research.

Advanced Scientific Computing Research Budget Allocation
FY 2008



Research

48 percent of the ASCR program's FY 2008 funding will be provided to scientists at universities and laboratories to conduct research. National laboratory research scientists work together with the other programs of SC 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.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2006, the ASCR program supported over 130 grants to the nation's university researchers and graduate students engaged in civilian applied mathematics, large-scale network, and computer science research. In addition, ASCR supports a Computational Science Graduate Fellowship (CSGF) and an Early Career Principal Investigator (ECPI) activity in Applied Mathematics, Computer Science, and High-Performance Networks. In FY 2006, CSGF activity selected 20 new graduate students representing 16 universities and 12 states. Approximately half of those who received Ph.D.'s in the CSGF program between 1991 and 2001 are pursuing careers outside universities or national labs. ASCR also provides support to other SC research programs. The ECPI activity made 7 new awards to early career principal investigators in FY 2006.

The university grants program is proposal driven, similar to the computer science and applied mathematics programs at the National Science Foundation (NSF). However, ASCR grant solicitation notices are focused on topics that have been identified as important for DOE missions and specifically include the long-term goals of ASCR. ASCR funds the best among the ideas submitted in response to grant solicitation notices that are published at http://www.grants.gov. Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605 (http://www.science.doe.gov/production/grants/605index.html).

- ***National Laboratory Research***: ASCR supports national laboratory-based research groups at Argonne, Brookhaven, Los Alamos, Lawrence Berkeley, Lawrence Livermore, Oak Ridge, Pacific Northwest, and Sandia National Laboratories and Ames Laboratory. 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 SC. Laboratory researchers collaborate with other laboratory and academic researchers, and are important for developing and maintaining testbeds, novel applications of high performance computing, long-term development of software tools, and networking in SC research. At Los Alamos, Livermore, and Sandia, ASCR funding plays an important role in supporting basic research that can improve programs, such as NNSA's Advanced Scientific Computing and Science-Based Stockpile Stewardship programs.

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.

Significant Program Shifts

The ASCR program has been a leader in the computational sciences for several decades and has been acknowledged for pioneering accomplishments. The FY 2008 ASCR budget is focused in priority areas identified by the joint Office of Management and Budget (OMB) and Office of Science and Technology Policy (OSTP) Research Priorities memorandum.

Major elements of the ASCR portfolio related to SciDAC were recompeted in FY 2006, resulting in support for further enhancements and scaling to petaflop computers of software tools such as mathematical libraries, adaptive mesh refinement software, and scientific data management tools developed in the first 5 years of the effort. Also, efforts initiated in FY 2006 in mathematical methods, computer science and visualization to enable simulations on the path to petascale will be continued. Finally, in FY 2008, ASCR will continue funding the competitively selected SciDAC institutes which can become centers of excellence in high-end computational science in areas that are critical to DOE missions.

The demands of today's facilities, which generate millions of gigabytes per year of data, now far outstrip the capabilities of the public Internet. The evolution of the telecom market, including the availability of direct access to optical fiber at attractive prices and the availability of flexible dense wave division multiplexing (DWDM) products gives SC the opportunity to exploit these technologies to provide scientific data where it is needed at speeds commensurate with the growing data volumes. To take advantage of this opportunity, ESnet has entered into a long term partnership with Internet 2 to build the next generation optical network infrastructure needed for U.S. science.

The ORNL LCF, selected under the Leadership Computing Competition in FY 2004, will continue its evolution into a true leadership facility. The LCF as well as the enhancement of NERSC are aligned with the plan developed by the HECRTF established by OSTP. This area has been identified as a priority within the overall Networking and Information Technology Research and Development (NITRD) priorities of the Administration.

In FY 2007, further diversity of LCF resources will be realized with the acquisition by ANL of a high performance IBM Blue Gene P with low-electrical power requirements and a peak capability of up to 100 teraflops. In FY 2008, the IBM Blue Gene P at ANL LCF will be expanded to 250–500 teraflops. The expansion of the Leadership Computing Facility to include the Blue Gene computer at ANL was an important element of the joint ORNL, ANL, and PNNL proposal selected in 2004. This capability will accelerate scientific understanding in areas that include molecular dynamics, materials science and biology.

Eighty percent of LCF resources are made available to the open scientific community, including industry, through the Office of Science's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program with no requirement of DOE funding. INCITE projects, including those on the Leadership Computing Facilities, are characterized by substantial allocations for a small number of high-impact scientific applications and are selected through a fully open peer review and computational readiness review process.

As a result of the INCITE call for proposals issued July 27, 2006, eighty-eight proposals were received requesting over 184 million processor hours in 2007 allocations. Additionally INCITE renewal projects requested an additional 75 million processor hours for 2007. The proposals represented the following scientific disciplines: accelerator physics, astrophysics, chemical sciences, climate research, computer science, engineering physics, environmental science, fusion energy, life sciences, materials science, nuclear physics, and nuclear engineering. Following both readiness and peer reviews, over 95 million hours were awarded for 26 new and 19 renewal INCITE projects.

These changes were made to help ensure the continued quality, relevance, and performance of ASCR programs. All ASCR activities undergo prospective and retrospective merit reviews and our extensive use of partnerships with other SC programs ensures the relevance of our efforts to SC missions.

Interagency Environment

The activities funded by the MICS subprogram are coordinated with other Federal efforts through the National Information Technology Research and Development (NITRD) subcommittee of the National Science and Technology Council and its Technology Committee. The NITRD Subcommittee provides active coordination for the multiagency NITRD Program. The Subcommittee is made up of representatives from each of the participating NITRD agencies and from the Office of Management and Budget (OMB), OSTP, and the National Coordination Office for IT R&D (NCO/IT R&D). The Subcommittee coordinates planning, budgeting, and assessment activities of the multiagency NITRD enterprise. 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. While the DOE program solves mission critical problems in scientific computing, results from the DOE program benefit the Nation's information technology basic research effort. The FY 2007 program positions DOE to make additional contributions to this effort. In the area of high performance computing, ASCR has extensive partnerships with other Federal agencies and the National Nuclear Security Administration (NNSA). Examples include: participating in the program review team for the Defense Advanced Research Projects Agency (DARPA) High Productivity Computing Systems program; serving on the planning group for the Congressionally mandated Department of Defense (DOD) plan for high performance computing to serve the national security mission; co-chairing the Office of Science and Technology Policy (OSTP) High End Computing Revitalization Task Force; and extensive collaboration with NNSA-Advanced Simulation and Computing. In FY 2003, ASCR formalized many of these interactions by developing a Memorandum of Understanding with SC, NNSA, DOD's Under Secretary for Defense

Research and Engineering, DARPA, and the National Security Administration to coordinate research, development, testing, and evaluation of high performance computers.

At the direction of the Senate's Energy and Water Development Appropriations Committee, ASCR and the NNSA Advanced Simulation and Computing program co-funded a study by the National Research Council on the Future of Supercomputing. The final report of the study, *Getting Up to Speed: The Future of Supercomputing*, was issued in 2005 and assessed the state of U.S supercomputing capabilities and relevant research and development (*Getting Up to Speed: The Future of Supercomputing*, Susan L. Graham, Marc Snir, and Cynthia A. Patterson, Editors, The National Academies Press, Washington, D.C., 2005).

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC mission areas with the goal of achieving breakthrough scientific advances via computer simulation that were impossible using theoretical or laboratory studies alone. SciDAC has pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit state-of-the-art computing and networking resources.

In FY 2006, ASCR recompeted its SciDAC portfolio, with the exception of activities in partnership with the Office of Fusion Energy that were initiated in FY 2005. In addition, in FY 2007 ASCR will continue the competitively selected SciDAC institutes which can become centers of excellence in high end computational science in areas that are critical to DOE missions. New SciDAC activities include Centers for Enabling Technologies, Science Applications and Scientific Applications Partnerships, and SciDAC Institutes.

Centers for Enabling Technologies (CETs), which replace the Integrated Software Infrastructure Centers (ISICs) from prior budgets, address the mathematical and computing systems software environment elements of the SciDAC scientific computing software infrastructure. The CETs are laboratory-university partnerships and address needs for: new algorithms that scale to parallel systems having hundreds-of-thousands of processors; methodology for achieving portability and interoperability of complex high-performance scientific software packages and libraries; operating systems and runtime tools and support for application execution performance and system management; and effective tools for analyzing, managing, visualizing and extracting scientific results from petabyte-scale scientific data sets obtained both from large-scale simulation and from laboratory experiment. CETs provide the essential computing and communications infrastructure for support of SciDAC applications.

Scientific Applications Partnerships (SAPs) are partnerships with other SC Programs and with some of the applied programs in the Department to integrate advanced applied mathematics and computer science technologies into specific SciDAC applications projects such as Genomics: GTL, Combustion, or the Fusion Simulation Project. Although the technical focus of SAPs is similar to that of CETs, the two program elements are complementary. First, the mathematicians and computer scientists funded by SAPs focus on the needs of specific science application teams and link these teams to the CET efforts which are larger and focus on software and mathematical tools that can be used by multiple applications teams. Second, SAPs provide the mechanism to supply application teams the computer science and mathematics expertise not covered by CET teams in order to fill important technical gaps.

SciDAC Institutes provide for the sustained infusion of new ideas and community focus to enhance the SciDAC program by building a broader community of researchers who understand the challenges of providing and using high-performance modeling and simulation capabilities and are willing to address these problems collaboratively. The SciDAC Institutes are university-led centers of excellence intended to complement the efforts of the other SciDAC program elements, and will provide a forum for discussion of fundamental computational issues affecting scientific discovery. SciDAC Institutes will be patterned on successful institute models in other scientific communities.

Scientific Facilities Utilization

The ASCR program's FY 2008 budget request includes support to the NERSC, ESnet, and the LCFs, located at ORNL's CCS and ANL. The investment in NERSC will provide computer resources for about 2,500 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 SC research programs. The investment in ESnet will provide 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 SC researchers and research facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, supercomputers, and other high impact scientific instruments. The investment in LCFs will deliver unclassified high performance capability resources to scientific researchers. The proposed funding will allow the high performance resources at the ANL LCF to be upgraded to a peak capability of 250–500 teraflops by the end of FY 2008. The ORNL-LCF will be on a path to one petaflop peak capability by the end of FY 2008.

	FY 2006	FY 2007 Estimate	FY 2008 Estimate
NERSC			
Maximum Hours	8,760	8,760	8,760
Scheduled Hours	8,585	8,585	8,585
Unscheduled Downtime	1%	1%	1%
ESnet			
Maximum Hours	8,760	8,760	8,760
Scheduled Hours	8,585	8,585	8,585
Unscheduled Downtime	1%	1%	1%
LCF-ORNL			
Maximum Hours	7,008	7,008	7,008
Scheduled Hours	7,008	7,008	7,008
Unscheduled Downtime	1%	1%	1%
LCF-ANL			
Maximum Hours	—	TBD[a]	6,000
Scheduled Hours	—	TBD	6,000
Unscheduled Downtime	—	1%	1%

[a] Inadequate basis for making reliable estimates at this time.

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational and computer science Ph.D. level scientists for the Department and the Nation through graduate student and postdoctoral research support. In FY 2008, this program will support approximately 415 graduate students.

ASCR will continue the Computational Science Graduate Fellowship Program with the selection of 20 new students in FY 2006 to support the next generation of leaders in computational science.

	FY 2006	FY 2007 Estimate	FY 2008 Estimate
# University Grants	135	150	170
Average Size (whole dollars)	$197,000	$197,000	$197,000
# Laboratory Groups	155	165	165
# Graduate Students	350	375	415
# Permanent Ph.D.s	625	670	720

Mathematical, Information, and Computational Sciences

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Mathematical, Information, and Computational Sciences			
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	109,631	117,122	129,910
High Performance Computing and Network Facilities and Testbeds	118,751	193,030	201,126
SBIR/STTR	—	8,502	9,162
Total, Mathematical, Information, and Computational Sciences	228,382	318,654	340,198

Description

The Mathematical, Information, and Computational Sciences (MICS) subprogram is responsible for carrying out the mission of the ASCR program: To deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, addressing a range of science issues that include the function of living cells and the power of fusion energy.

Benefits

MICS supports ASCR's contribution to DOE's mission by providing world-class, peer-reviewed scientific results in mathematics, high performance computing and advanced networks and applying the potential of terascale computing to advanced scientific applications. Computer-based simulation enables us to predict the behavior of complex systems that are beyond the reach of our most powerful experimental probes or our most sophisticated theories. Computational modeling has greatly advanced our understanding of fundamental processes of nature, such as fluid flow and turbulence or molecular structure and reactivity. Through modeling and simulation, we will be able to explore the interior of stars and learn how protein machines work inside living cells. We can design novel catalysts and high-efficiency engines. Computational science is increasingly central to progress at the frontiers of almost every scientific discipline and to our most challenging feats of engineering. Accordingly, we must address the following questions:

- What new mathematics are required to more effectively model systems such as the earth's climate or the behavior of living cells that involve processes taking place on vastly different time and/or length scales?
- Which computational architectures and platforms will deliver the most benefit for the science of today and the science of the future?
- What advances in computer science and algorithms are needed to increase the efficiency with which supercomputers solve problems?
- What operating systems, data management, analysis, model development, and other tools are required to make effective use of future-generation supercomputers?
- What tools are needed to make all scientific resources readily available to scientists, regardless of whether they are at a university, national laboratory, or industrial setting?

To answer these questions and develop the algorithms software and tools that are needed, MICS has developed four strategies (the strategy numbers refer to the SC Strategic Plan):

6.1 Advance scientific discovery through research in the computer science and applied mathematics required to enable prediction and understanding of complex systems.

6.2 Extend the frontiers of scientific simulation through a new generation of computational models that fully exploit the power of advanced computers, and through collaboratory software that makes scientific resources available to scientists anywhere, anytime.

6.3 Bring dramatic advances to scientific computing challenges by supporting the development, evaluation, and application of supercomputing architectures tailored to science.

6.4 Provide computing resources at the petascale and beyond, network infrastructure, and tools to enable computational science and scientific collaboration.

All MICS investments directly contribute to one or more of these strategies.

Supporting Information

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 and to develop software tools, libraries, and environments. Results from enabling research supported by the MICS subprogram are used by computational scientists supported by other SC and 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—24 hours a day, 365 days a year—to researchers working on problems relevant to DOE's scientific missions.

The Early Career Principal Investigator (ECPI) activity was initiated in FY 2002 for scientists and engineers in tenure track positions at U.S. universities. Since that time 62 awards have been made including six awards in FY 2006. The goal of the ECPI activity is to support SC 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.

FY 2006 Accomplishments

- ***NERSC to increase peak capacity by factor of 100.*** NERSC, through the competitive procurement process for NERSC-5, evaluated a number of vendors, using the NERSC Sustained System Performance (SSP) metric. The SSP metric was developed by NERSC to better gauge how well a proposed system will meet the needs of the Center's 2,500 users and measures sustained performance on a set of codes selected to accurately represent the Center's portfolio of challenging scientific applications. Based on the evaluations, NERSC selected a 100 teraflop Cray Hood system. The system will consist of over 19,000 AMD Opteron 2.6-gigahertz processor cores, with two cores making up one node. Each node has 4 gigabytes of memory resulting in aggregate memory capacity of 39 terabytes.
- ***Leadership Computing Facility doubles XT3 capability to 54 teraflops.*** The LCF at ORNL upgraded the Cray XT3 supercomputer to increase the system's computing power to 54 teraflops.

The LCF system is currently the largest high performance computing system in SC and will become a major computing resource for DOE's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program. The upgrade involved replacing all 5,212 single core processors with Cray's dual-core processors, doubling the memory and increasing the bisection bandwidth resulting in a supercomputer that consists of more than 10,400 processing cores and 21 terabytes of memory. The upgrade will allow the LCF to provide additional resources for computationally intensive, large-scale projects with the potential of high scientific impact such as the design of innovative nanomaterials, predictive simulations of fusion devices and the understanding of microbial molecular and cellular systems.

- ***ESnet moves forward with new architecture to deliver cost effective, high reliability, high performance networks for science.*** Energy Sciences Network (ESnet) is implementing a new architecture that is a double core ring with interconnected metropolitan area networks (MANs). The new architecture is designed to meet the increasing demand for network bandwidth, high reliability, and advanced network services as next-generation scientific instruments and supercomputers come on line. In FY 2006, the second and third MANs were completed in the Chicago and New York-Long Island areas. They provide dual connectivity at 20 gigabits per second—10 to 50 times the previous site bandwidths, depending on the site using the ring—while reducing the overall cost. These MANs connect ANL, Fermi National Accelerator Laboratory (FNAL), and BNL to the ESnet backbone to address critical requirements such as Large Hadron Collider (LHC) data. By increasing bandwidth to these sites, DOE advances research in areas such as climate change, genetics, renewable energy, nanotechnology, national security, and basic science in physics and chemistry through support for the large-scale science and large-scale SC collaborations nationwide.
- ***Lambda Station enables High Energy Physics researchers to prepare for LHC.*** Lambda Station, a high-capacity software-based network technology device, which combines advanced optical networks technologies with ultra high-speed data-intensive applications, has enabled researchers at FNAL, bracing for an onslaught of data from LHC experiments, to develop ultra fast connections for moving US-CMS (the U.S. part of the Compact Muon Solenoid detector) data between LHC Tier1 and Tier2 centers. Initial test results using Lambda Station technology enabled FNAL, the US-CMS Tier1 center to transfer data at line rate (10 gigabits per second) to Caltech, a US-CMS Tier2 center. This transfer rate represents a 15 fold increase in file system to file system transfer speed.
- ***Simulations on Massively Parallel (32,000 Processor) Architectures Provide New Insights into Galaxies.*** ANL applied mathematicians have developed Nek5000, an advanced scientific simulation tool, that features high-order numerical discretizations and multigrid solvers capable of scaling to thousands of processors. Such extreme scalability is needed to simulate magnetohydrodynamics in complex domains. A major advance this year was the port of Nek5000 to the 32,000-processor Blue Gene platform at IBM Watson, where the researchers were able to identify an unexpected linear angular vector profile during their study of angular momentum transport in galaxies.
- ***Unified Parallel C implements one-sided messages to improve scientific software performance on high performance computers.*** Partitioned Global Address space languages offer an alternative to message passing programming on high end systems. LBNL and University of California groups recently demonstrated that the languages can effectively leverage modern network hardware to provide performance that is faster than the two-sided send/receive models for some machines and computations. One example is the communication-intensive 3D Fast Fourier Transform (FFT),

important to many scientific simulations. The compilers for these languages are highly portable and support interoperability with the Message Passing Interface, Fortran, and C/C++ languages.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	**109,631**	**117,122**	**129,910**
▪ **Applied Mathematics**	**32,022**	**29,495**	**36,900**

This activity supports research on the underlying mathematical understanding of physical, chemical, and biological systems, and on advanced numerical algorithms that enable effective description, modeling, and simulation of such systems on high-end computing systems. It directly supports SC Strategic Plan strategy 6.1. Research in Applied Mathematics supported by the MICS subprogram underpins computational science throughout DOE. Historically, the numerical algorithms developed under this activity have produced scientific advances through simulation that are as significant as those resulting from 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 solution 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); automated reasoning systems; and multiscale mathematics; risk assessment and optimization of complex systems. This final area represents a new effort focusing on those mission-related applications involving control in complex systems.

In FY 2008, this activity is increased to support critical long-term mathematical research issues relevant to petascale science (+$2,000,000), research in optimization control and risk analysis in complex systems (+$1,900,000), and research in multiscale mathematics (+$2,505,000). Support for multiscale mathematics is $11,000,000 in FY 2008. The Computational Science Graduate Fellowship Program is also increased by $1,000,000, bringing the total to $5,000,000.

▪ **Computer Science**	**31,763**	**23,863**	**29,000**

This activity supports research in computer science to enable computational scientists to effectively utilize petascale computers to advance science in areas important to the DOE mission. This activity supports SC Strategic Plan strategies 6.1 and 6.3. 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 petascale computers with hundreds or thousands of processors as well as computers that are located at different sites; and large-scale data management and visualization for both local and remote data analysis. Research areas include: scalable tools to diagnose and monitor the performance of scientific applications and enable users to improve performance and get scientific results faster; new programming models that scale to hundreds of thousands of processors to simplify application code development for petascale computing; advanced techniques for visualizing very large-scale scientific data; and efforts to improve petascale application performance through innovative next generation operating systems. Researchers at DOE laboratories and universities, often working in partnerships, propose and conduct this research.

All of the computer science research funded by this activity is reported to and coordinated through the High End Computing Interagency Working Group of the NITRD Subcommittee. The quality, relevance, and performance of the program is continually monitored through extensive peer review, interagency reporting and coordination, and interaction with end users to assist in the determination of impact and future research priorities.

Beginning in FY 2004, this activity incorporated the software research component of the implementation of the HECRTF plan to improve application performance and system reliability through innovative approaches to next generation operating systems. This activity is coordinated with other agencies through the High End Computing University Research Activity (HECURA), an outgrowth of the HECRTF. These activities were modestly increased to $5,363,000 in FY 2007, especially in areas such as performance analysis of innovative high-end architectures; frameworks for data intensive and visual computing; intelligent program development environments; application-specific problem solving environments; and common compile and runtime infrastructures and interfaces, where ASCR is the leader in the Federal agency research efforts. This research will play a key role in the interagency strategy for high-end software development.

Beginning in FY 2008, the Computer Science activity will have a focus on strengthening long-term research in computer science to ensure that scientific applications can fully exploit future hardware performance. In the software environment area, additional funding (+$4,137,000) will focus on developing software and tools (focused on integrated/intelligent software development environments and new generation debugging and performance analysis tools providing improved ease-of-use at the petascale) to enable both experienced and new researchers to make effective use of petascale scale systems at the national Leadership Computing Facilities (LCFs) and at the supercomputer facilities. In the data analyses, management, and visualization area (+$1,000,000), we will focus on accelerated visualization, uncertainty and user interface environments.

	FY 2006	FY 2007	FY 2008
▪ **Computational Partnerships**	**28,796**	**50,000**	**50,246**

This activity supports Scientific Discovery through Advanced Computing (SciDAC). The advanced computing software tools part of this activity supports research and development activities that extend key results from applied mathematics and computer science research to develop integrated software tools that computational scientists can use in high performance scientific 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 such systems. This activity directly supports SC Strategic Plan strategy 6.2.

In FY 2008, this activity will support SciDAC Centers for Enabling Technologies (CET) and SciDAC Institutes that were competitively selected in FY 2006.

The CETs funded under this activity ($21,000,000), both university-led and national laboratory-led, will address the mathematical and computational systems software environment of the SciDAC computing software infrastructure. This infrastructure envisions a comprehensive, integrated, scalable, and robust high performance software environment, which overcomes difficult technical challenges to enable the effective use of terascale and petascale systems by SciDAC applications. CETs address needs for: new algorithms which scale to petascale computing systems having hundreds-of-thousands of processors; methodology for achieving portability and interoperability of complex high performance scientific software packages; operating systems and runtime tools and support for application execution performance and system management; and effective tools for feature identification, data management, and visualization of petabyte-scale scientific data sets. The CETs work closely with application scientists to develop and introduce software into application codes.

The SciDAC Institutes ($7,000,000) are university-led centers of excellence which complement the efforts of the SciDAC CETs but with a role in the development of the next generation of computational scientists. The SciDAC Institutes focus on application codes and are in turn dependent on the algorithms and software developed by the high-performance computer science community. The SciDAC Institutes activities will include: efforts to develop, test, maintain, and support optimal algorithms, programming environments, systems software and tools, and applications software; focus on a single general method or technique (for example, large scale optimization for engineering problems); be a focal point for bringing together a critical mass of leading experts from multiple disciplines to focus on key problems in a particular area of enabling technologies; and reach out to engage a broader community of scientists to advance in scientific discovery through advanced computation, collaboration, training of graduate students and postdoctoral fellows.

The FY 2008 request also includes $22,246,000 for Scientific Applications Partnerships (SAPs) that support collaborative research of applied mathematicians and computer scientists with domain scientists to develop and apply computational techniques and tools to address problems relevant to the SC mission. 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.

In the competitively selected FY 2006 SciDAC awards, partnerships have been formed with SC programs in Basic Energy Sciences (BES), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), and Nuclear Physics (NP), and with the National Nuclear Security Administration (NNSA). The projects are part of the SciDAC activity and are coupled to the SciDAC CETs and Institutes. Areas under investigation include nuclear physics (HEP, NP, and NNSA); petascale data (HEP); accelerator physics and design (HEP); computational astrophysics (HEP, NP, and NNSA); quantum chromodynamics (NP); computational biology,

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

ground water modeling and simulation, and climate models (BER); plasma turbulence in tokamaks (FES); turbulence, materials science and chemistry (BES and NNSA). This activity directly supports SC Strategic Plan strategy 6.2.

The FY 2008 request for SAPs includes $16,000,000 to continue the competitively selected FY 2006 SciDAC awards, as well as the partnerships with the BER Genomics: GTL program, the BES program in nanoscale science, and the FES program for the Fusion Simulation Project (FSP).

▪ **Distributed Network Environment Research**	**17,050**	**13,764**	**13,764**

This activity builds on the fundamental results of computer science to develop integrated software tools and advanced network services to enable large-scale scientific collaboration and make effective use of distributed computing and science facilities to advance the DOE science mission. The activity supports research and development in three areas: 1) distributed systems software, tools, and services to enable the discovery, management, and distribution of petabyte-scale data sets generated by simulations or by science experiments such the Large Hadron Collider (LHC) in HEP and ITER ($3,000,000) in FES, 2) advanced network protocols, optical network services, tools, and protocols to interconnect and provide access to LCFs and science facilities ($7,764,000); and 3) high-performance middleware to facilitate secure national and international scientific collaborations ($3,000,000). This activity will enable SC to exploit new capabilities being made available by ESnet and other national research and education networks to provide scientific data where it is needed at speeds commensurate with the new data volumes.

All research in this activity is reported to and coordinated with the Large-Scale Networking (LSN) Interagency Working Group of the NITRD Subcommittee. This activity builds the understanding that will enable ESnet as well as other Research and Education Networks such as the Internet2 Abilene network to fully take advantage of the opportunity to make optical networks tools for science. In much the same way that early scientific use of the Internet enabled today's worldwide infrastructure, the experience of scientists on these new optical networks is expected to influence the next generation of high performance networks for the country. For example, it includes standards-based network protocols and middleware that address challenging issues such as security, information location, and network performance that are encountered with ultra-high-speed data transfers, remote visualization, real-time remote instrumentation, and large-scale scientific collaboration. These tools provide a new way of organizing and performing scientific work, e.g., distributed teams and real-time remote access to SC facilities that offers the potential for increased productivity and efficiency. It 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 across the research enterprise.

High Performance Computing and Network Facilities and Testbeds	**118,751**	**193,030**	**201,126**
▪ **High Performance Computing Facilities and Testbeds**	**94,985**	**170,294**	**176,790**

This activity directly supports SC Strategic Plan strategy 6.4 through a portfolio of capabilities that range from Research and Evaluation Prototypes (R&E Prototypes) to Leadership Computing

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Facilities (LCFs) to High Performance Production Computing (HPPC). This activity integrates activities previously described separately as NERSC and ACRTs. It includes NERSC and resources at the ORNL and ANL LCFs. Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware are also supported at a reduced level in FY 2008.

	FY 2006	FY 2007	FY 2008
• **High Performance Production Computing**	**37,489**	**54,790**	**54,790**

This activity supports the National Energy Research Scientific Computing Center (NERSC), located at the LBNL. NERSC delivers high-end capacity computing services and support to the entire DOE SC research community and provides the majority of resources and services that are used to support SC SciDAC programs. The center serves 2,500 users working on about 400 projects. 56% of users are university based, 33% are in National Laboratories, 7% are in other government laboratories, and 4% are in industry. FY 2008 funding will support the continued operation of NERSC 3e at 10 teraflops peak performance, and the computer systems, NCSa and NCSb, with a combined peak performance of 10 teraflops and NERSC-5. NCSa and NCSb are focused on high performance production computing for scientific applications that do not scale well to more than 512 processors and are not well suited to the NERSC 3e. In addition, the next generation of high performance resources at NERSC, NERSC-5, scheduled to be delivered in FY 2007 will have a peak capacity between 100–150 teraflops. These computational resources are integrated by a common high performance file storage system that enables users to easily migrate to any of the resources. With the acquisition of NERSC-5, the capacity at NERSC increased by about a factor of 6.

In FY 2008, NERSC will continue to play a key role in the SC strategy for computational science because it enables teams to prepare to make the best use of the Leadership Computing Facilities (LCF) as well as to perform the calculations that are required by the missions of SC. In FY 2008, $29,435,000 is dedicated to hardware procurement, $4,836,000 to user support services, $4,506,000 to utilities, and $16,013,000 to other support costs.

	FY 2006	FY 2007	FY 2008
• **Leadership Computing Facilities (LCF)**	**53,630**	**102,504**	**105,000**

The LCF activity was initiated with a call for proposals in FY 2004. As a result of the peer-reviewed competition, the partnership established by ORNL, ANL, and PNNL was selected to provide capability computing resources for SC researchers. Eighty percent of LCF resources are made available to the open scientific community, including industry, through SC's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program with no requirement of DOE funding. INCITE projects, including those on the Leadership Computing Facilities, are characterized by substantial allocations for a small number of high-impact scientific applications and are selected through a fully open peer review and computational readiness review process.

	FY 2006	FY 2007	FY 2008
▸ **Leadership Computing Facility at ORNL**	**53,036**	**80,000**	**77,000**

The first LCF capability for science was established in late FY 2005 at ORNL with the acquisition of a Cray X1E, the most capable system available to scientific users in the U.S., and a complementary Cray Red Storm (XT3) system. In FY 2007, the ORNL LCF will

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

upgrade the Cray XT3 to a peak capacity of 100 teraflops and will be on the path to one petaflop in FY 2008.

In FY 2008, the ORNL LCF will continue to provide world leading high performance sustained capability to researchers on a peer-reviewed basis. The acquisition of a 1 petaflop Cray Baker system in late FY 2008 will enable further scientific advancements such as simulations of diesel combustion that could lead to cleaner energy from coal and simulations of fusion devices that approach ITER scale devices and quantum Monte Carlo calculations of complex chemical reactions that extend over experimentally relevant times. The success of this effort is built on the enhancements to the research and evaluation prototype and computer science research activities elsewhere. In FY 2008, $37,195,000 is dedicated to hardware procurement, $9,906,000 to user support services, $4,892,000 to utilities, and $25,007,000 to other support costs.

	FY 2006	FY 2007	FY 2008
▸ **Leadership Computing Facility at ANL**	**594**	**22,504**	**28,000**

In FY 2007, further diversity with the LCF resources was realized with an acquisition by ANL of a high performance IBM Blue Gene P with low-electrical power requirements and a peak capability of up to 100 teraflops. The expansion of the Leadership Computing Facility to include the Blue Gene computer at ANL was an important element of the joint ORNL, ANL, and PNNL proposal selected in 2004.

In FY 2008, the IBM Blue Gene P at ANL LCF will be expanded to 250–500 teraflops. This capability will accelerate scientific understanding in areas that include molecular dynamics, catalysis, protein/DNA complexes, and aging of materials. In FY 2008, $17,741,000 is dedicated to hardware procurement, $4,822,000 to user support services, $1,788,000 to utilities, and $3,649,000 to other support costs.

	FY 2006	FY 2007	FY 2008
• **Research and Evaluation Prototypes**	**3,866**	**13,000**	**17,000**

The Research and Evaluation Prototype computer activity will prepare users for the next generations of scientific computers and reduce the risk of major procurements. This activity will be carried out in close partnership with the NNSA and the DARPA HPCS program. This effort is critical to address the challenges of the systems that will be available by the end of the decade. These systems will be ten times larger than those of today. Many of the issues that need to be addressed are shared with the computer science research effort described above. This activity includes the SC partnership in the DARPA HPCS Phase III program ($13,000,000) as well as support for SC's participation in the joint SC-NNSA partnership with IBM to explore low power density approaches to petascale computing ($4,000,000).

	FY 2006	FY 2007	FY 2008
▪ **High Performance Network Facilities and Testbeds**	**23,766**	**22,736**	**24,336**

This activity directly supports SC Strategic Plan strategy 6.4 to provide high capability networking services to support leading edge scientific research. This strategy integrates ESnet, a Wide Area Network (WAN) project that supports the scientific research mission of the DOE with a number of smaller Metropolitan Area Networks (MANs). ESnet provides high bandwidth access to the ESnet backbone to provide national and international high-speed access to DOE and SC researchers and

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

research facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, supercomputers, and other high impact scientific instruments.

In FY 2008, SC Networks will take advantage of the partnership between ESnet and the Internet2, which was announced in August 2006, to implement the next generation optical network infrastructure for U.S. science. At this funding level in FY 2008 ($24,336,000), ESnet will deliver a 10 gigabit per second (gbps) core Internet service as well as a Science Data Network with 20 gbps on its northern route and 10 gbps on its southern route. The success of this effort builds on the tools and knowledge developed by the Distributed Network Environment Research effort described above to enable SC to realize the promise of optical networks for DOE missions. $13,315,000 is dedicated to procuring data services, $7,211,000 to support services, and $3,810,000 to the research partnership with Internet2.

	FY 2006	FY 2007	FY 2008
Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR)	**—**	**8,502**	**9,162**

In FY 2006, $5,627,000 and $675,000 were transferred to the SBIR and STTR programs respectively. The FY 2007 and FY 2008 amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs.

	FY 2006	FY 2007	FY 2008
Total, Mathematical, Information, and Computational Sciences	**228,382**	**318,654**	**340,198**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	
▪ **Applied Mathematics**	
The increase will support critical long-term mathematical research issues relevant to petascale science, multiscale mathematics, and optimization control and risk analysis in complex systems as well as a $1,000,000 increase in the Computational Science Graduate Fellowship Program to $5,000,000.	+7,405
▪ **Computer Science**	
This increase will focus on strengthening long-term research in computer science to ensure that scientific applications can fully exploit future hardware performance. In the software environment area, additional funding will have a focus on developing software and tools to enable both experienced and new researchers to make effective use of petascale scale systems at the LCFs and supercomputer facilities. In data analyses, management and visualization, focus will be on accelerated visualization, uncertainty and user interface environments.	+5,137

	FY 2008 vs. FY 2007 ($000)
▪ **Computational Partnerships**	
Additional funds will continue the competitively selected FY 2006 SciDAC awards as well as the partnerships with the BER Genomics: GTL program, the BES program in nanoscale science, and the FES program for the Fusion Simulation Project (FSP).	+246
Total, Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	**+12,788**
High Performance Computing and Network Facilities and Testbeds	
▪ **High Performance Computing Facilities and Testbeds**	
• **Leadership Computing Facilities (LCFs)**	
The IBM Blue Gene P at ANL LCF will be expanded to 250–500 teraflops. This capability will accelerate scientific understanding in areas that include molecular dynamics, catalysis, protein/DNA complexes, and aging of materials. The ORNL LCF will operate the 250 teraflop Cray XT4 system and prepare to accept the 1 Petaflop follow on system.	+2,496
▪ **Research and Evaluation Prototypes**	
This activity will be expanded to support the DOE-DARPA HPCS partnership as well as the SC-NNSA Low Power Density petaflop computing partnership with IBM.	+4,000
▪ **High Performance Network Facilities and Testbeds**	
This increase will enable ESnet in FY 2008 to deliver a 10 gigabit per second (gbps) core Internet service as well as a Science Data Network with 20 gbps on its northern route and 10 gbps on its southern route.	+1,600
Total Funding Change, High Performance Computing and Network Facilities and Testbeds	**+8,096**
SBIR/STTR	
Increase in SBIR/STTR due to increase in operating expenses.	+660
Total Funding Change, Mathematical, Information, and Computational Sciences	**+21,544**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Capital Equipment	5,771	15,000	13,000

Biological and Environmental Research

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Biological and Environmental Research			
Life Sciences	197,695	264,158	282,343
Climate Change Research	136,630	134,909	138,124
Environmental Remediation	91,190	97,196	97,430
Medical Applications and Measurement Science	138,562	14,000	14,000
Total, Biological and Environmental Research	564,077[a]	510,263	531,897

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the Biological and Environmental Research (BER) program is to advance environmental and biological knowledge that promotes national security through improved energy production, development, and use; international scientific leadership that underpins our Nation's technological advances; knowledge needed to support the President's National Energy Plan; and research that improves the quality of life for all Americans. BER supports these missions through competitive and peer-reviewed research at national laboratories, universities, and private institutions.

Benefits

BER supports DOE's mission of protecting our national and economic security by providing scientific research capacity and advancing scientific knowledge by supporting peer-reviewed scientific research in biology and environmental science that produces results published in the scientific literature. Basic biological and environmental research has broad impacts on our energy future, our environment, and our health. An ability to predict long-range and regional climate enables effective planning for future needs in energy, agriculture, and land and water use. By understanding complex biological systems and developing computational tools to model and predict their behavior, biotechnology solutions are possible for DOE energy, environmental, and national security challenges. For example, biology-based solutions for energy production can be developed by understanding and utilizing the incredible complexity and potential of plants and microbes. Understanding the global carbon cycle and the associated role and capabilities of microbes and plants can lead to solutions for reducing carbon dioxide concentrations in the atmosphere. Understanding the complex role of biology, geochemistry, and hydrology beneath the Earth's surface will lead to improved decision making and solutions for contaminated DOE weapons sites as well as other sites for which DOE has environmental stewardship responsibility. Development of advanced radiotracers, new imaging instruments, and novel biomedical devices can improve

[a] Total is reduced by $5,857,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $14,066,000, which was transferred to the SBIR program; and $1,688,000, which was transferred to the STTR program.

understanding of both normal and abnormal health—from normal human development to cancer to brain function. 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.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The BER program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

The BER program has one GPRA Unit Program Goal which contributes to Strategic Goal 3.1 and 3.2 in the "goal cascade."

GPRA Unit Program Goal 03.1/2.47.00: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and facilitate the entrainment of physical sciences advances in the biomedical field.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

BER contributes to Strategic Goals 3.1 and 3.2 by advancing fundamental world-class, merit-reviewed research in genomics, proteomics, climate change, environmental remediation, radiation biology, and medical imaging. Discoveries at these scientific frontiers will bring revolutionary and unconventional solutions to some of our most pressing and expensive challenges in energy and the environment.

We intend to understand how living organisms interact with and respond to their environments to be able to use biology to produce clean energy, remove excess carbon dioxide from the atmosphere, and help clean up the environment. Our understanding the causes and consequences of global climate change and our ability to predict climate over decades to centuries may enable us to develop science-based solutions to minimize the potential adverse impacts of climate change and to better plan for our Nation's future energy needs and resource use. Understanding the biological effects of low doses of radiation could lead to the development of science-based health risk policy to better protect workers and citizens. Understanding the fate and transport of environmental contaminants may lead the way to discovering innovative approaches for cleaning up and monitoring the environment.

BER research leads to the development of advanced medical imaging technology, including radiopharmaceuticals for use in diagnosis and treatment of disease. BER research currently supports the development of an artificial retina that will enable the blind to see.

This research capitalizes on the national laboratories' resources and expertise in biological, chemical, physical, and computational sciences, and on their sophisticated instrumentation (neutron and light sources, mass spectroscopy, and high field magnets), lasers and supercomputers. This research is coordinated with and complementary to other Federal programs.

In addition, BER plans, constructs, and operates reliable, scientific facilities to serve thousands of researchers at universities, national laboratories, and private institutions from all over the world. Activities include structural biology research beam lines at the synchrotron light sources and neutron sources; the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) (including the

Molecular Sciences Computing Facility) where research activities support long-term environmental remediation and other DOE missions in energy and national security; the Production Genomics Facility (PGF) for DNA sequencing; and the Atmospheric Radiation Measurement (ARM) facilities for climate change research.

The following indicators establish specific long-term goals in Scientific Advancement that the BER program is committed to, and progress can be measured against.

- **Life Sciences:** Provide the fundamental scientific understanding of plants and microbes necessary to develop new robust and transformational basic research strategies for producing biofuels, cleaning up waste, and sequestering carbon.
- **Climate Change Research:** Deliver improved scientific data and models about the potential response of the Earth's climate and terrestrial biosphere to increased greenhouse gas levels for policy makers to determine safe levels of greenhouse gases in the atmosphere.
- **Environmental Remediation:** Provide sufficient scientific understanding such that DOE sites would be able to incorporate coupled physical, chemical and biological processes into decision making for environmental remediation and long-term stewardship.
- **Medical Applications and Measurement Science:** Develop intelligent biomimetic electronics that can both sense and correctly stimulate the nervous system.[a]
- **Facilities:** Manage facilities operations to the highest standards of overall performance using merit evaluation with independent peer review.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goal 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 03.1/2.47.00, Harness the Power of Our Living World			
Biological and Environmental Research	564,077	510,263	531,897

[a] This indicator is not a PART measure.

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 03.1/2.47.00 (Harness the Power of Our Living World)					
Life Sciences					
Increase the rate of DNA sequencing: Produce at least 14 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing: Produce at least 20 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2005 at least 28 billion base pairs will be sequenced. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2006 at least 30 billion base pairs will be sequenced. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing – Cost reductions will increase the number of high quality base pairs determined (less than one error in 10,000 bases) by 25% from the FY 2006 target of 582 base pairs per dollar to 781 base pairs per dollar.	Increase the rate and decrease the cost of DNA sequencing of microbial and model organism genomes. Cost reductions will increase the number of high quality base pairs determined (less than one error in 10,000 bases) by 10% from the FY 2007 actuals.
Climate Change Research					
Improve climate models: Constructed a climate model for the next round of IPCC Working Group 1 Assessment simulations. This model increased the realism of the coupled atmosphere-ocean-land surface-sea ice system through improvements in the physical parameterizations, particularly the cloud sub models. The standard model increased the horizontal resolution to 1.4 degrees in the atmosphere and maintained the 0.7 degree resolution in the ocean and sea ice components. More objective and systematic methods to test (evaluate) the performance of both the model components (i.e., atmosphere, ocean, land surface, and sea ice sub models) as well as the fully coupled model, were applied. [Met Goal]	Improve climate models: Implement a model test bed system to incorporate climate data rapidly into climate models to allow testing of the performance of sub-models (e.g. cloud resolving module) and model parameters by comparing model simulations with real world data from the ARM sites and satellites. [Met Goal]	Improve climate models: Implement three separate component submodels (an interactive carbon cycle submodel, a secondary sulfur aerosol submodel, and an interactive terrestrial biosphere submodel) within a climate model and conduct 3-4 year duration climate simulation using the fully coupled model. [Met Goal]	Improve climate models: Produce a new continuous time series of retrieved cloud properties at each ARM site and evaluate the extent of agreement between climate model simulations of water vapor concentration and cloud properties and measurements of these quantities on the timescale of 1 to 4 days. [Met Goal]	Provide new mixed-phase cloud parameterization for incorporation in atmospheric GCMs and evaluate extent of agreement between climate model simulations and observations for cloud properties in the arctic.	Report results of decade-long control simulation using geodesic grid coupled climate model and produce new continuous time series of retrieved cloud, aerosol, and dust properties, based on results from the ARM Mobile Facility deployment in Niger, Africa.

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
Environmental Remediation					
Determine scalability of laboratory results in field environments: Identified naturally occurring microbial populations responsible for transformation of metals and radionuclides at DOE contaminated sites. [Met Goal]	Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales: Quantify contaminant immobilization and remobilization by different factors: 1. natural microbial mechanisms; 2. chemical reactions with minerals; and 3. colloid formation. [Met Goal]	Determine scalability of laboratory results in field experiments - Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings. [Met Goal]	Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests. [Met Goal]	Implement a field-oriented, integrated experimental research program to quantify coupled processes that control reactive transport of at least one key DOE contaminant.	Identify the critical redox reactions and metabolic pathways involved in the transformation/ sequestration of at least one key DOE contaminant in a field environment.
Medical Applications and Measurement Science[a]					
Advance blind patient sight: Developed and tested materials for platform and sealants for a prototype artificial retina- a microelectronic array to be used for the treatment of blindness. [Met Goal]	Advance blind patient sight: Complete fabrication of 60 microelectrode array for use as an artificial retina and tested in animal subject. [Met Goal]	Advance blind patient sight: Complete testing on a 60 microelectrode array artificial retina and insert prototype device into a blind patient. [Goal Not Met]	Advance blind patient sight: Begin testing of prototypes for 256 microelectrode array artificial retina. [Met Goal]	Advanced blind patient sight: complete design and construction of final 256 electrode array. Begin in vitro testing and non-stimulating testing in animals.	Advance blind patient sight: Complete in vitro testing of 256 electrode array and continue animal studies of final design 256 electrode array.
All BER Facilities					
Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]	Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]	Maintain and operate BER facilities (Life Science – PGF and the Mouse facility; Climate Change Research – ARM and FACE; and Environmental Remediation – EMSL) such that achieved operation time is on average greater than 90% of the total scheduled annual operation time for each group of facilities. [Met Goal]	Maintain and operate BER facilities (Life Science – PGF and the Mouse facility; Climate Change Research – ARM and FACE; and Environmental Remediation – EMSL) such that achieved operation time is on average greater than 95% of the total scheduled annual operation time for each group of facilities. [Met Goal]	Maintain and operate BER facilities (Life Science – PGF and the Mouse facility; Climate Change Research – ARM and FACE; and Environmental Remediation – EMSL) such that achieved operation time is on average greater than 98% of the total scheduled annual operation time for each group of facilities.	Maintain and operate BER facilities (Life Science – PGF; Climate Change Research – ARM; and Environmental Remediation – EMSL) such that achieved operation time is on average greater than 98% of the total scheduled annual operation time for each group of facilities.

[a] This is not a PART measure.

Means and Strategies

The BER program will use various means and strategies to achieve its program goals. However, various external factors may impact the ability to achieve these goals.

The BER program will continue its investments in core fundamental science and technologies needed to address the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. Of highest priority will be the Genomics: GTL program which supports the development of a new research infrastructure needed to understand fundamental biological principles underlying the function and control of biological systems. This new research infrastructure of 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 production and environmental cleanup.

Our ability to predict climate on global and regional scales, to develop strategies for the removal of excess carbon dioxide (suspected to adversely impact global climate) from the atmosphere, and to provide the science to underpin the prediction of the impacts of climate change, will depend on the continued development of novel research tools and a close integration of experimental, observational, and computational research.

BER also plays a key role in constructing and operating a wide array of biological and environmental user facilities for the Nation's researchers, such as the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), the Production Genomics Facility (PGF), and the Atmospheric Radiation Measurement (ARM) facilities.

All BER-supported research projects undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) mission needs as described by the DOE and SC mission statements and strategic plans; (2) evolving scientific opportunities that sometimes revolutionize disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or subfields, such as those performed by the National Academies of Science; (4) unanticipated failures, for example, in critical components of scientific user facilities that cannot be mitigated in a timely manner; and (5) strategic and programmatic decisions made by other (non-DOE) Federal agencies and by international entities.

The BER program is closely coordinated with the activities of other federal agencies (e.g., National Institutes of Health [NIH], National Science Foundation [NSF], National Aeronautics and Space Administration [NASA], Department of Commerce/National Oceanic and Atmospheric Administration [NOAA], Environmental Protection Administration [EPA], Department of Agriculture [USDA], and Department of Defense [DOD]). BER Climate Change Research is coordinated with the U.S. Global Change Research Program, an interagency program codified by Public Law 101-606 and involving thirteen federal agencies and departments.

BER also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of future energy sources, improved use of fossil fuels (carbon sequestration), reduced environmental impacts of energy production and use, and environmental cleanup and monitoring.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The Biological and Environmental Research Program has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the BER program a score of 86% overall which corresponds to a rating of "Effective". The assessment found that BER has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this Budget Request, BER grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain our scientific performance measures, the Office of Science developed a website (http://www.sc.doe.gov/measures) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Biological and Environmental Research Advisory Committee (BERAC), will guide triennial reviews by BERAC of progress toward achieving the long term Performance Measures. These roadmaps are posted on the SC website. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has previously provided BER with three recommendations to further improve performance:

- Engaging the National Academies in an independent assessment of the scientific basis and business case for the program's microbial genomics research efforts. [Action completed]

  In response, BER has engaged a committee of the National Research Council (NRC) of the National Academies to review the design of the Genomics: GTL program and its infrastructure plan. The committee was directed to specifically examine whether the program was scientifically and technically well-tailored to the challenges faced by the DOE in energy technology development and environmental remediation. The NRC committee report, *Review of the Department of Energy's Genomics: GTL Program* (available at http://DOEGenomestoLife.org), released in May, 2006, provided a strong endorsement of the Office of Science GTL program, recommending that the program's focus on systems biology for bioenergy, carbon sequestration, and bioremediation be given a "high priority" by DOE and the nation. But the report also recommended that the program's plan for new research facilities be reshaped to produce earlier and more cost-effective results. The NRC committee recommended that the GTL facilities should be focused not on particular technologies, but on research underpinning particular applications – bioenergy, carbon sequestration, or environmental remediation.

  In response to the report and the NRC recommendations, the Office of Science has revised its original single-purpose user facilities plan to instead develop and support vertically-integrated GTL Research Centers to accelerate systems biology research. The vertically-integrated GTL Research

Centers will not require construction of facilities. These centers will not only possess the robust scientific capabilities needed to carry out their broad mission mandates, but also draw upon the broader GTL program for technology development and foundational research. The GTL program will integrate these capabilities and advanced technologies with the robust computational infrastructure needed to better understand the genomic potential, cellular responses, regulation, and behaviors of biological systems. The first research centers will have a focus on bioenergy research; subsequent centers will focus on other aspects of bioenergy research, environmental remediation and carbon sequestration.

- Implementing the recommendations of past external panel reviews of the program's research portfolio and management practices. [Actions are completed and/or on-going as appropriate]

  In response, BER is using external panels (Committee of Visitors – COVs) to review the quality, relevance, and performance of its research portfolio and grant management practices. COVs findings and BER responses can be viewed at http://www.sc.doe.gov/measures/FY06.html.

- Reviewing operations of user facilities, and improving discrimination in identifying open user facilities versus collaborative research facilities. [Actions are completed and/or on-going as appropriate]

  BER conducted reviews of the Joint Genome Institute Production Genomics Facility (JGI/PGF) and EMSL facilities, and a review of ARM facilities is scheduled in FY 2007.

In November 2005, a BERAC subcommittee panel conducted a comprehensive review of the science, management, and operations of the DOE JGI/PGF. The committee gave high marks to the JGI with respect to scientific vision, the implementation of the role of the JGI as a user-facility and its focus on DOE mission objectives, and to the PGF for its state of the art operations with respect to cost, quality, and quantity of sequences that it produces. The JGI/PGF, in addition to functioning as an effective national user facility, has also served effectively as a lead organization in collaborations on DOE missions. This is especially evident in its pioneering approaches to the area of metagenomics, defining a unique niche for the PGF that does not overlap with other sequencing facilities and is highly aligned with DOE missions. The review was supportive of the new Laboratory Science Program at the JGI, providing guidance on its management structure, and operational and mission drivers. The review panel identified opportunities for improvements in reporting and operational procedures, but noted no serious deficiencies.

BER conducted a June 2006 follow-on review of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) to validate the corrective actions taken in response to the management and operations findings of the BERAC and Office of Science/Office of Project Assessment reviews in May, 2005. These reviews validated the status of EMSL as a National Scientific User Facility. The June 2006 review committee found that actions taken in response to the May 2005 reviews were "timely, comprehensive, and on target" and that implementation of those actions was "effective, widely accepted, and appears to be on its way to completion" by the end of FY 2006.

In FY 2007 the ARM facilities will be reviewed by BERAC.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov web site. Information concerning BER PART assessments and current follow up actions can be found by searching on "biological environmental research" at http://www.ExpectMore.gov.

Overview

BER supports basic research in genomics, proteomics, radiation biology, climate change, environmental remediation, 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 BERAC.

The Opportunity

With the 21st Century dawns what many have called the "biological century"–an era when advances in biology, spurred by achievements in genomic research and led by the sequencing of the human genome, will bring revolutionary and unconventional solutions to some of our most pressing and expensive challenges in energy, the environment, national security, and health.

The Challenges

A new biology—Can we understand the workings of biological systems, both plants and microbes, 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 and complex microbial communities and sophistication of diverse plants, each with exquisitely precise and efficient functions and controls, will enable us to use and even redesign these molecular machines, microbes, or plants to address DOE and national needs.

Understanding and predicting climate—Advanced climate and Earth system models are needed to describe and predict the roles of oceans, the atmosphere, sea ice, and land masses on climate, including the interactions and feedbacks between the various components of the climate system. So too, the role of clouds and aerosols in controlling solar and terrestrial radiation onto and away from the Earth needs to be better understood since their effects are still a major source of uncertainty in climate prediction. Moreover, the impacts of excess carbon dioxide in the atmosphere from human activities, including energy use, on Earth's climate and ecosystems need to be determined and possible mitigation strategies developed.

A cleaner environment—The Department of Energy faces the country's largest set of environmental remediation challenges, many of which currently have no solutions. The Department's environmental clean up objectives require advances in our understanding of the biological, chemical and physical processes that control contaminant mobility in the environment. Sufficient understanding will allow accurate predictions of future conditions and the ability to make informed decisions regarding the need for and types of remedial actions at a given site. This understanding also will provide the foundation for novel and more effective clean up and monitoring technologies needed to implement such action. Many remediated sites have intractable residual contamination that will require long-term stewardship, including monitoring and actions to ensure protection of human health and the environment.

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. Furthermore, understanding the biological effects of low doses of radiation will lead to the development of science-based health risk policy to better protect workers and citizens.

The Investment Plan

All BER Research and Development (R&D) investments are evaluated against the Administration's R&D Investment criteria that include research and user facility relevance, quality, and performance. BER will continue its investments in core technologies and fundamental science needed to address these daunting challenges. BER believes 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. BER investments at these interfaces may enable: (1) the development of a new research infrastructure for understanding the function and control of biological systems that can be used to solve critical problems in energy and the environment; (2) understanding the biological effects of low doses of radiation that will lead to the development of science-based health risk policy to better protect workers and citizens, (3) an improved ability to predict climate on global and regional scales; (4) development of strategies to remove excess carbon dioxide from the atmosphere; (5) new science-based strategies for the remediation, and long-term monitoring of the environment; and (6) the development of unique devices and technologies for the medical community.

How We Work

BER uses a variety of mechanisms to conduct, coordinate, and fund 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 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 solicits 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 and subcommittees created by the National Science and Technology Council and the Office of Science and Technology Policy (OSTP). BER, as a collaborative partner in interagency programs, such as the U.S. Climate Change Science Program, also consults with and receives advice from some boards and panels of the National Academies of Science and its National Research Council. 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; Legacy Management, Civilian Radioactive Waste Management, Energy Efficiency and Renewable Energy; Nuclear Energy, Science and Technology; 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 Interagency Genomics and Biotechnology working groups, the combined Climate Change Science Program and U.S. Global Change Research Program, and the National Institutes of Health Bioengineering Consortium. Finally, BER consults regularly with groups like JASON, 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 genomics program.

Facility Operations Reviews

All BER facility operations are monitored by peer reviews and user feedback as previously discussed.

BER manages all 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, merit review, and user feedback are critical tools for BER to measure performance of research programs, research projects, and user facilities. The quality and scientific relevance of the BER program and its individual research projects are maintained by rigorous peer reviews conducted by internationally recognized scientific experts. The criteria for determining scientific quality and relevance include scientific merit, appropriateness of the proposed approach, and reasonableness of the requested level of funding, 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 of funded scientists 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 Climate Change Science Program and the structural biology research program, including reviews by Boards and Committees of the National Academies of Science and its National Research Council.

Planning and Priority Setting

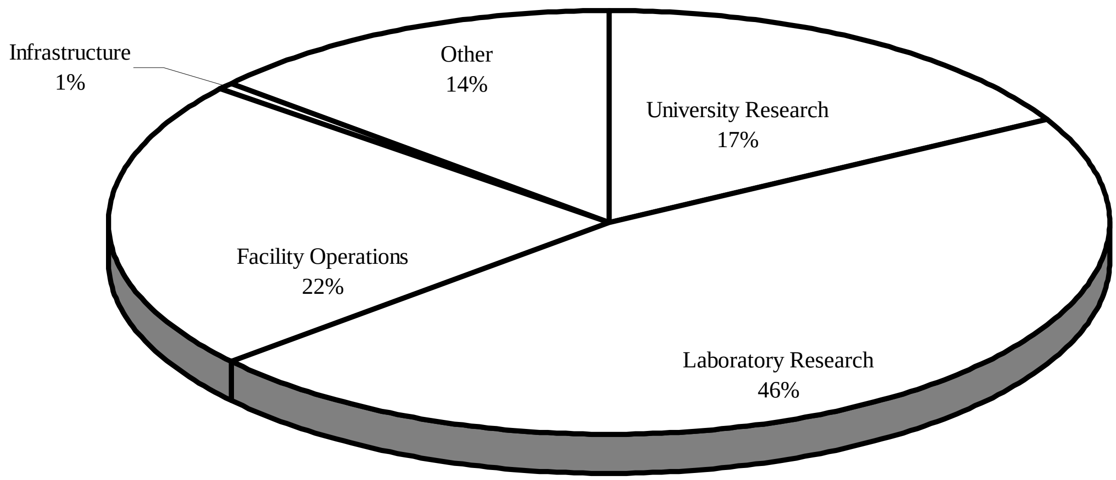
BER supports research and develops new research initiatives across many fields of science that bring together many different disciplines, including biology, chemistry, engineering, computing, and the physical sciences. Merit reviews and user feedback are incorporated as BER anticipates and plans for the future needs of DOE research in the biological and environmental sciences. This includes planning for future directions and opportunities, within the BER research portfolio; maintaining the flexibility to quickly move into promising new areas; contributing to the health of the educational pipeline in 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 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., Genomics: GTL, low dose radiation research, genomic DNA sequencing, global climate change research, environmental remediation research, and medical sciences develop long-range program plans through coordinated efforts with BERAC and other federal agencies.

How We Spend Our Budget

The BER budget has three major components: basic research at universities (17%); basic research at national laboratories (46%); and user facility operations (22%). The remaining 15% includes general plant projects and equipment that supports the research infrastructure at the national laboratories (1%) and all other research activities (primarily other federal agencies and industry (14%)). Research at national laboratories also includes the Environmental Remediation Sciences field research sites and other elements that represent a research infrastructure for the scientific community that is available to both university and laboratory scientists. BER's user facilities (Facility Operations - 22%) include the infrastructure at synchrotron and neutron sources for structural biology and the environmental sciences, operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), support for high-throughput DNA sequencing at the Joint Genome Institute, and Atmospheric Radiation Measurement Infrastructure (including the ARM Aerial Vehicles).

Biological and Environmental Research Budget Allocation
FY 2008



Research

In FY 2008, the BER program will support research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical sciences at over 200 public and private research institutions in over 40 states, and at 14 DOE laboratories in 10 states. This research will be conducted in over 1,000 different research projects by over 2,500 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 Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

- ***University and Private Sector 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. Private sector research institutions are playing an increasingly important role in BER biological and medical research. BER will continue its commitment to and dependence on scientists at the Nation's universities and private research institutions.

  In general, BER-supported research activities at universities and at private sector research institutions are single and multi-investigator projects. Increasingly, this research is also becoming multi-institutional, commonly including collaborations with DOE laboratories. University scientists are the major scientific users at BER facilities that include the ARM program, DNA sequencing, structural biology, and EMSL.

All research projects supported by the BER program undergo regular merit review and evaluation based on the procedures set down in 10 CFR Part 605 for the extramural grant program (http://www.science.doe.gov/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 most 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 infrastructure including the EMSL, ARM Facilities, Environmental Remediation Sciences Research Field Research Center (FRC), the Joint Genome Institute (JGI), and the structural biology and environmental user facilities at the synchrotron.

  All DOE laboratory research projects supported by the BER program undergo regular merit 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.

BER Leadership and Unique Roles

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

- Manage research on microbes and plants for energy and the environment 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 cutting edge technologies, facilities (including high-throughput community DNA sequencing capabilities), and resources for genomics research;
- Provide scientific user facilities for environmental molecular research;
- Provide leadership in low dose radiation research;
- Provide leadership in ground-based measurement of clouds and atmospheric properties and processes to resolve key uncertainties in climate change; and development of advanced predictive capabilities using coupled climate and Earth system models on the Nation’s premier computers for decade-to-century long simulations of climate change;
- Provide leadership to understand, predict and control processes that determine the fate and transport of metal and radionuclide contaminants in the subsurface environment;
- Provide support of science at the interface of physics, chemistry, materials, and computation to develop an artificial retina; and
- Ensure that the rights and welfare of human research subjects at the DOE laboratories or in activities using DOE funds are protected while advances in biomedical, environmental, nuclear, and other research lead to discoveries that benefit humanity.

Significant Program Shifts

- BER will fund the first two GTL Bioenergy Research Centers (to be selected and partially funded in FY 2007) and will add a third center; all three will conduct fundamental research on microbes and plants needed to produce biologically-based fuel.
- The Ethical, Legal, and Societal Issues (ELSI) research will increase to further explore issues related to biotechnology and nanotechnology, including the ecological effects of nanoparticles.
- JGI/PGF sequencing will continue to address mission-relevant genomes of plants, microbes, and microbial communities, including the initiation of the Laboratory Science Program (LSP) to stimulate participation in GTL-relevant sequencing at the national laboratories. The LSP will complement the success of the existing Community Sequence Program (CSP).
- BER will continue research at the Laboratory for Comparative and Functional Genomics ("Mouse House"). However, BER will no longer fund the Mouse House as a user facility. BER's programmatic need for this facility has greatly decreased with the completion of human genome related research and the growth of the GTL program. There is still a broad need for mouse genetic resources in the scientific community, especially at the National Institutes of Health. BER's Low Dose Radiation Research activity will continue to fund research at the "Mouse House."
- Free Air Carbon Dioxide Enrichment (FACE) experiments to study the direct effect of elevated carbon dioxide and other trace gases on terrestrial ecosystems will no longer be operated as user facilities. Research on the effects of carbon enrichment on terrestrial ecosystem structure and functioning will continue under Terrestrial Carbon Processes Research and Ecosystem Function and Response Research. The activity is best characterized as field experiments in which multiple investigators jointly participate as collaborators to understand the direct effect of elevated carbon dioxide and other trace gases on terrestrial ecosystems rather than as a user facility.
- The Climate Change Research Subprogram will enhance climate modeling research to address strategic questions in abrupt climate change, including, incorporating mechanisms into coupled climate models, and testing the models vis-à-vis records of past abrupt climate change.
- The Environmental Remediation Sciences subprogram will conduct research at two additional field research sites (total of 3), one at Hanford, Washington and the other at Old Rifle, Colorado. The sites were selected by merit review in late 2006. The existing site at Oak Ridge, Tennessee will continue. This will provide new opportunities to validate laboratory findings under field conditions, to provide DOE-relevant samples to other investigators, and to support additional SciDAC research to develop improved models for the reactive flow and transport of subsurface contaminants, and provide information for geologic carbon sequestration.

Genomics: GTL Research

The FY 2008 budget includes funds for the continued expansion of the Genomics: GTL program—a program at the forefront of the biological revolution. This program employs 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. It will determine the diverse biochemical capabilities of DOE relevant microbes, microbial communities, and plants, with the goal of tailoring and translating those capabilities into solutions to DOE mission needs.

Development of a global biotechnology based energy infrastructure requires a science base that will enable scientists to control or redirect genetic regulation; and redesign specific proteins, biochemical pathways, and even entire plants or microbes. Renewable biofuels could be produced using plants, microbes, or isolated enzymes. Understanding the biological mechanisms involved in these energy producing processes may allow scientists and technologists to design novel biofuel production strategies involving both cellular and cell free systems that might include defined mixed microbial communities or consolidated biological processes. Within the Genomics: GTL program, BER will develop the understanding needed to advance biotechnology-based strategies for biofuel production, focusing on renewable, carbon-neutral energy compounds such as ethanol and hydrogen.

Cellulose to Ethanol—Advanced Biological Production of Ethanol—Ethanol produced from corn starch is currently the most widely consumed biofuel in the United States, used as a substitute or octane booster for gasoline. A gallon of ethanol has about two-thirds the energy content of a gallon of gasoline. The production of cellulosic ethanol from biomass has promise for meeting a portion of U.S. gasoline demand. A workshop convened jointly by the Office of Science's Biological and Environmental Research program and the Office of Energy Efficiency and Renewable Energy's (EERE) Biomass program resulted in a research roadmap for cellulosic ethanol research through concerted application of modern biology tools ("Breaking the Biological Barriers to Cellulosic Ethanol: A Joint Research Agenda," available at www.doegenomestolife.org/biofuels/; DOE/SC-0095). This joint research agenda, pairing the research goals of the Office of Science with the commercialization pathway of the Office of Energy Efficiency and Renewable Energy, could provide the tools for industry to develop better feedstocks and improve conversion processes, resulting in biofuel production at a scale needed to make a real difference in transportation consumption of fossil fuels. Research will be supported that provides a systems-level understanding of biological processes for developing and deploying large-scale, environmentally sound biotechnologies to produce ethanol from plant biomass, primarily lignocellulosic material. Currently, a biochemical conversion of biomass to ethanol involves three basic steps: (1) breakdown of raw biomass using heat and chemicals, (2) use of enzymes to breakdown plant cell wall materials into simple sugars, and (3) conversion of the sugars into ethanol using microbes. Research will support the development of new biological and chemical tools to provide detailed understanding of plant cell walls, their roles in plant function, and factors controlling recalcitrance and optimization of processes for fermentation of sugars. Research will also support the identification of genes involved in the synthesis of cell-wall polymers and higher structures; reactions performed by the multitude of enzymes involved; design principles of cell walls; and factors controlling the amounts, composition, and structure of polymers and polymer matrices. Discovery of new biomass-degrading organisms across many different kingdoms of life—including plants, fungi, and bacteria—will also expand our capabilities relevant to biomass conversion to biofuels.

DOE and other relevant agencies utilize guidance from the Biomass Technical Advisory Committee and the Biomass R&D Board established under the Biomass Research and Development Act of 2000 to integrate R&D across agencies. In 2006, the Board began preparation of an interagency National Biofuels Action Plan. This plan will be followed by a comprehensive interagency coordination and planning document that will be reviewed by the National Academies beginning in late 2007. In addition to assessing the goals and plans for interagency biomass research, the Academy will be tasked with considering economic and other impacts of increased biomass utilization under various energy price and policy scenarios.

BER and USDA have conducted two joint solicitations for genomics-based research that will lead to improved feedstocks for cellulosic ethanol. BER and the Basic Energy Sciences (BES) program complement each other's research programs; distinguished primarily by BER's emphasis on biological solutions that are aimed at understanding and manipulating the metabolic pathways, and BES's emphasis on understanding the photosynthetic process and aimed at the intersection with chemical sciences and physics, such as self-assembly of biomaterials.

This research is expected to lead to a fundamentally new process and biorefinery paradigm that could enable an efficient and economic industry for converting plant biomass to liquid fuels.

The FY 2008 request includes $15,000,000 for bioethanol research.

Biological Production of Hydrogen–Some microorganisms produce hydrogen naturally, and biotechnologies based on these microbial systems could lead to the development of clean, renewable sources of hydrogen. Through a process known as biophotolysis, green algae and cyanobacteria can use energy from the sun to split water and generate hydrogen. Other anaerobic microbes can generate hydrogen from conversion of biomass or sugars, a process known as dark fermentation. Fundamental research will be supported to understand biophotolysis and dark fermentation processes, well enough that predictive models of hydrogenase (the enzyme that cleaves water to produce hydrogen) structure and function, metabolite and reductant flux through metabolic pathways, genetic regulatory and biochemical networks, and eventually entire microbes can be developed. Research will include investigations on a range of hydrogen-producing enzymes and organisms, applying directed evolution or synthetic biology approaches to create improved hydrogenases with greater catalytic efficiency and oxygen resistance, metabolic engineering to redirect the flux of reductants or substrates through fermentation pathways, and systems biology to optimize genetic regulatory and biochemical processes that influence hydrogen production. This new knowledge will be used to engineer the ideal microbe or to construct stable microbial consortia to use in hydrogen bioreactors and fuel cells.

As with ethanol research, above, BER and BES also complement each other's hydrogen research programs in similar ways: BER is more focused on genomics and BES is more focused on understanding at the molecular and atomic level.

The FY 2008 request includes $15,000,000 for biohydrogen research.

Climate Change Science Program

In 2003, the Administration launched the Climate Change Research Initiative (CCRI) to focus research on areas where substantial progress in understanding and predicting climate change, including its causes and consequences, is possible over the next five years. The CCRI was then combined with the existing U.S. Global Change Research Program (USGCRP) to form a combined USGCRP/CCRI managed as the Climate Change Science Program (CCSP) by the cabinet-level Committee on Climate Change Science and Technology Integration. (The BER request for CCSP for FY 2008 is $129,585,000.) DOE, in conjunction with its interagency partners, including NSF, NASA, NOAA, USDA, Interior, and EPA, will continue to focus its Climate Change Research in CCSP priority areas. These areas include abrupt climate change, advanced climate modeling, critical climate processes (including effects of clouds and water vapor on the atmospheric radiation balance), carbon cycling, atmospheric composition (with a focus on both greenhouse gas concentrations and effects of various aerosols on climate), effects of climate change on important terrestrial ecosystems, and the development and evaluation of tools for assessing environmental costs and benefits of climate change and the different potential options for mitigation and adaptation to such change. The deliverables from this BER research are expected to be useful to policy makers.

In FY 2008, BER will contribute to the CCRI from four programs: Terrestrial Carbon Processes, Climate Change Prediction, ARM, and Integrated Assessment. Activities will be focused on (1) helping to resolve the North American carbon sink question (i.e., the magnitude and location of the North American carbon sink); (2) deployment and operation of a mobile ARM facility to provide data on the effects of clouds and aerosols on the atmospheric radiation budget in regions and locations of opportunity where data is lacking or sparse; (3) using advanced climate models to simulate potential effects of natural and human-induced climate forcing on global and regional climate and the potential effects on climate of alternative options for mitigating increases in human forcing of climate, including abrupt climate change; and (4) developing and evaluating assessment tools needed to study costs and benefits of potential strategies for reducing net carbon dioxide emissions.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all Office of Science mission areas with the goal of achieving breakthrough scientific advances via computer simulations that are impossible using theoretical or laboratory studies alone. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit terascale computing and networking resources.

In FY 2008, BER will continue to advance the science of climate and Earth system modeling by coupling models of different components of the earth system related to climate and by significantly increasing the spatial resolution of such models. These SciDAC-enabled activities will allow climate scientists to gain unprecedented insights into interactions and feedbacks between, for example climate change and global biogeochemical cycling of carbon and the potential effects of carbon dioxide and aerosol emissions from energy production and use on the global climate system.

BER will add SciDAC components to GTL and Environmental Remediation research. GTL SciDAC will initiate new research to develop mathematical and computational tools needed for complex biological system modeling and for analysis of complex data sets from metabolomic or proteomic profiling. Environmental Remediation SciDAC will provide opportunities for subsurface and computational scientists to develop and improve methods of simulating subsurface reactive transport processes. The intent is to explore potential advantages that high-end computing can bring to the understanding of optimal model complexity, the scalability of biogeochemical reactions, model abstraction methods, sources of uncertainty, parameter estimation and characterization measurements as input in subsurface reactive transport modeling. Such advances have application to environmental remediation, long-term environmental stewardship and carbon sequestration.

Scientific Facilities Utilization

The BER request includes funds to maintain support of the Department's major scientific user facilities. BER's facilities include the structural biology research beam lines at the synchrotron light sources and neutron sources; 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; the Joint Genome Institute Production Genomics Facility; and the Atmospheric Radiation Measurement facilities. 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 its user facilities so that the achieved operation time will be greater than 98%, on average, of total scheduled annual operation.

User Statistics[a]

	(estimated)		
	FY 2006	FY 2007	FY 2008
William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)			
Optimal hours	4,365	4,365	4,365
Scheduled hours	4,365	4,365	4,365
Operation Time	95%	>98%	>98%
Users	1600	1700	700[b]
Production Genomics Facility (PGF)			
Optimal hours	8,400	8,400	8,400
Scheduled hours	8,400	8,400	8,400
Operation Time	>98%	>98%	>98%
Users	80	120	120[c]
Atmospheric Radiation Measurement (ARM)			
Optimal hours	7,884	7,884	7,884
Scheduled hours	7,884	7,884	7,884
Operation Time	>98%	>98%	>98%
Users	800	850	900[d]

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 (BES) 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 within 10% of baseline estimates.

For BER activities, capital equipment is held at approximately the FY 2007 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 purpose 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

---

[a] Note, as explained in the Significant Program Shifts, FACE and the Laboratory for Comparative and Functional Genomics ("Mouse House") are now characterized as research activities rather than as user facilities.

[b] EMSL users are both onsite and remote. Beginning in FY 2008, BER will revise the definition of "User" for the EMSL. This change in definition is reflected in a revised target for FY 2008. Under the revised definition, individual users are counted once per year.

[c] All users are remote. Primary users are individuals associated with approved projects being conducted at the PGF in a reporting period. Each user is counted once per year regardless of how many proposals their name may be associated with.

[d] ARM users are both onsite and remote. A user is an individual who accesses ARM databases or uses equipment at an ARM site. Individuals are only counted once per reporting period at an individual site but may be counted at different ARM sites if they are a user at more than one site.

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 important 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 can be important for the development of the next generation of scientists, engineers, and science educators.

Specific fellowship programs for undergraduate and graduate students are also sponsored by BER through its Global Change Education Program to help develop the next generation of scientists needed for climate change research and to target emerging areas of need in such research.

About 1,500 graduate students and post-doctoral investigators will be supported collectively by all BER programs at universities and at national laboratories in FY 2008, including those conducting research at BER user facilities with BER or other funds. BER will continue its support for graduate students and post-doctoral investigators in FY 2008.

Office of Science user facilities also play a role in workforce development. Graduate and postdoctoral students from many different disciplines use Office of Science user facilities. For example, researchers in the environmental, biological, and physical sciences use the instruments at EMSL and the synchrotron light sources. The unique capabilities at these facilities provide graduate and postdoctoral students the opportunity to participate in leading-edge research. Approximately half of all DOE facility users are graduate or postdoctoral fellows, for example, some 600 to 700 students will conduct research at EMSL in FY 2008. Students who use EMSL receive their funding from a number of sources including the EMSL user (operating) budget, other BER projects, other DOE programs, other federal agencies, international sponsors, and private industry.

The fastest growing user community at the synchrotron light sources is environmental researchers. BER, working with BES, provides funding to each of the synchrotron light sources to support BER sponsored scientists as well as for maintenance and upgrade of environmental user stations. In addition, BER is working with scientists in the environmental research community who receive funding from DOE and other agencies to develop more environmental science user stations at the synchrotron light sources. This will further increase the impact of SC facilities on workforce development in important research fields, such as the environmental sciences.

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, university, and private sector scientists.

University-based scientists are the principal users of BER user facilities. University scientists also form the core of the science teams in the Climate Change Research Programs that network with the broader academic community as well as with scientists at DOE laboratories and 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, low dose radiation research, climate change research, and environmental remediation research. Furthermore, university scientists work in close partnership with scientists at national laboratories in BER programs including genomics, and carbon sequestration research.

		(estimated)	
	FY 2006	FY 2007	FY 2008
# University Grants	700	700	705
Average Size per year	$250,000	$250,000	$250,000
# Laboratory Projects	375	350	355
# Permanent Ph.D's[a]	1,321	1,291	1,320
# Postdoctoral Associates[b]	299	297	304
# Graduate Students[b]	436	423	429
# Ph.D.s awarded[c]	100	105	105

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007, the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

[a] Estimated. Information is not readily available on the total number of permanent Ph.D. scientists 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 Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.
[b] Estimated for national laboratory projects.
[c] Information is not available on the number of Ph.D.s awarded as a result of BER funded research at universities or national laboratories. Data is estimated.

Life Sciences

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Life Sciences			
Structural Biology	15,449	15,300	15,300
Molecular and Cellular Biology	112,571	159,942	179,462
Human Genome	60,823	74,575	72,733
Health Effects	8,852	7,321	7,321
SBIR/STTR	—	7,020	7,527
Total, Life Sciences	197,695	264,158	282,343

Description

The mission of the Life Sciences subprogram is to foster fundamental research, to develop novel technological capabilities for biological research, and to provide biological solutions to the DOE's energy and environmental mission needs. Life Sciences research is expected to deliver a new knowledge base for cost effective cleanup of environmental contamination, design of new strategies for enhanced capture of atmospheric carbon dioxide, rational design and improvement of new energy crops and increased bio-based sources of fuel or electricity. The program may also deliver new knowledge underpinning rigorous, cost-effective standards to protect the health of DOE cleanup workers and the public, and for science-based decisions on DOE site cleanup.

Benefits

Fundamental research is supported in genomics and systems biology, and the health effects of low dose radiation. DNA sequencing is used to understand the genetic and environmental basis of normal and abnormal biological function, from genes that make some people more sensitive to the adverse effects of low doses of radiation to the metabolic capabilities of mixed microbial communities that could be used to produce clean energy, clean up or stabilize wastes *in situ*, or sequester excess atmospheric carbon dioxide. Community user facility resources are made widely available for determining high-resolution protein structures at DOE synchrotrons, and high-throughput genomic DNA sequencing of microbes, microbial communities, and complex organisms such as plants. New capabilities are developed in the Genomics: GTL program for understanding the structure, function, and biochemical capabilities of complex, DOE-relevant microbial communities—information needed to develop biotechnological solutions for DOE needs.

Supporting Information

BER Life Sciences supports research and research infrastructure in the following areas:

- Bioenergy Research Centers conducting comprehensive, multidisciplinary, and integrated research programs in energy-related systems and synthetic biology.
- Genomics: GTL research, developing, together with the Advanced Scientific Computing Research program, experimental and computational resources, tools, and technologies to understand the complex behavior of biological systems – scaling from single microbes to communities of multiple microbial species to plants. This information can be used to develop innovative biotechnology

solutions for energy production, environmental mitigation, and carbon management, including biotechnological solutions for bioethanol and biohydrogen.

- A high-throughput DNA sequencing user facility to meet DNA sequencing needs of the scientific community in DOE mission areas.
- Biological effects of low doses of ionizing radiation. The program works closely with scientists, regulators, and the public to ensure that the research results are available to develop an informed scientific basis for effective radiation protection standards to protect DOE radiation and cleanup workers, and the public.

Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This subprogram was reviewed by a BERAC Committee of Visitors (COV) in FY 2005. The next scheduled review of the Life Sciences subprogram by a BERAC COV will be in FY 2008.

FY 2006 Accomplishments

- **Sequencing the Poplar Genome:** DOE national laboratories led an international collaboration to sequence the first tree genome, with the actual sequencing work on Populus trichocarpa, more commonly known as poplar, performed at the DOE Joint Genome Institute Production Genomics Facility. With a genome size of just over 500 million letters of genetic code, it is the most complex genome to be sequenced and assembled by a single public sequencing facility. The analysis of the genetic possibilities of the completed poplar sequence was published in the summer of 2006, revealing a substantial expansion of genes involved in carbon allocation to cellulose, lignin and flavonoid biosynthesis, disease resistance, meristem development and metabolite transport. The information encoded in the poplar genome will provide researchers with a critical resource to develop faster growing trees, trees that produce more biomass for conversion to biofuels such as ethanol, and trees that can sequester more carbon from the atmosphere or be used to clean up waste sites.
- **The 100th Microbial Genome:** U.S. Department of Energy Joint Genome Institute (DOE JGI) has finished the sequence of 100 microbial genomes and released this information for the benefit of the global research community. The microbes sequenced by DOE JGI, both single-celled and those multi-celled organisms invisible to the naked eye, cross all main branches of the tree of life: Eubacteria, Archaea, and even the Eukaryota, which include microscopic fungi, plants, and animals. The 100th microbial genome is *Methanosarcina barkeri fusaro*, a methane-producing organism that exploits a unique metabolic pathway to do the job. This metabolic flexibility helps this microbe to survive in diverse environments, from freshwater mud to the rumen of cattle where cellulose and other polysaccharides are digested. Microbes, thriving in even the world's most extreme environments, are capable of performing myriad biological functions, learned over the billions of years they have inhabited the planet. Those lessons, and how they can be captured to render clean renewable sources of energy and to repair damaged environments, are among the many secrets encoded in their DNA sequence.
- **Microbial Stress Management:** The microbe *Desulfovibrio vulgaris* Hildenborough adapts its physiology so it can survive in habitats containing toxic and radioactive metal wastes and fluctuating high levels of salt. Using a variety of approaches such as transcriptomics, proteomics, metabolite assays, and electron microscopy, GTL investigators applied a systems approach to explore the effects of excess salt on *D. vulgaris*. They discovered that this microbe’s coping mechanisms include importation of protective small molecules, the up-regulation of pump systems and the ATP synthesis

(metabolic energy) pathway, changes in the stability of nucleic acids, changes in cell wall fluidity, and an increase in the activity of chemotaxis genes. The systems-level integration of data from multiple methods has led to a conceptual model for salt stress response in *D. vulgaris* that can now be compared to other microorganisms, leading to general, predictive models of microbial stress response and adaptation.

- **Microbial Electricians—Wired for Energy:** *Geobacter* and *Shewanella* are versatile microbial performers for cleaning up toxic waste, due in part to their useful metabolic ability to extract radioactive and toxic metals from the surrounding soil and water, shuttling electrons in the process. Linked to this ability to "breathe" on metals, rather than oxygen, these microbes build long, thin extracellular filaments that are associated with electron-shuttling, membrane-bound cytochromes. Since these filaments, 20,000 times finer than a human hair, have been found to conduct electricity, they are often called "nanowires." It's not known what these nanowires are made of, how they are assembled, or what their biological function is. However, these nanowires may be common to other microbes and microbial consortia dependent on electron transfer. Furthermore, nanowires could be responsible for cell-to-cell electron transfer processes in biofilms and complex microbial mat communities. On a more practical note, nanowires in the photosynthetic microbe *Synechocystis* have been used to construct solar-powered microbial fuel cells, perhaps leading to additional strategies for energy transduction systems.
- **Marine Plankton Mix it Up:** *Crenarchaeota* comprise an estimated 20% of all planktonic microbes; their sheer abundance thus renders them a significant influence on biogeochemical cycling in marine ecosystems. GTL science has predicted important components in the reconstruction of carbon and energy metabolism from the partial genome sequence of an uncultivated planktonic sample. The sequence reconstruction predicts the organism's ability to use carbon dioxide as a sole carbon source to produce building blocks in amino acid and cofactor biosynthesis, as well as reduced nitrogen compounds such as ammonia or urea to fuel energy metabolism. Thus genomics confirms what prior isotopic labeling studies suggested: under nutrient-poor conditions, these microbes have the capacity for light-independent autotrophic growth on simple compounds such as ammonia and carbon dioxide, whereas when organic material is readily available, these plankton can switch to mixotrophic growth. The conservation and ubiquity of planktonic pathways for carbon assimilation and ammonia oxidation substantiate the importance of these tiny plankton in marine ecosystems.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Structural Biology	**15,449**	**15,300**	**15,300**

The Structural Biology program develops and supports access to beam lines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and the NSF, the management and maintenance of 22 experimental stations at several DOE synchrotrons (Advanced Photon Source [APS], Advanced Light Source [ALS], and Stanford Synchrotron Radiation Laboratory [SSRL]). User statistics for all BER structural biology user facilities are included in the BES facility user reports. BER continually assesses the quality of the instrumentation at its experimental stations and supports upgrades to install the most effective instrumentation for taking full advantage of the facility capabilities as they are improved by DOE.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Molecular and Cellular Biology	**112,571**	**159,942**	**179,462**
▪ **Carbon Sequestration Research**	**7,663**	**7,127**	**7,127**

Microbes and plants play substantial roles in the cycling of carbon through the environment. Carbon sequestration research seeks to understand the fundamental mechanisms of carbon fixation, conversion, and cycling in microbes, microbial communities and plants. The program has initiated a new focus on carbon sequestration and utilization for biofuels, with genomics-based research that will lead to the improved use of biomass and plant feedstocks for the production of carbon-neutral fuels such as ethanol or renewable chemical feedstocks. This is part of the BER contribution to the Climate Change Technology Program (see the Climate Change Science subelement for additional information). Systems biology approaches are supported to yield fundamental knowledge of the structure, function and organization of plant genomes leading to increased carbon fixation and biomass yield, improved feedstock characterization and sustainability. Fundamental research focuses on understanding carbon uptake, fixation and storage in plants and soil microbes, strongly leveraging the increasing availability of information from whole organism genomes and community metagenomes. Research will also focus on understanding the role that microbial communities or plant-microbe associations play in the transfer of carbon between the roots and the soil, to identify strategies that would lead to increased carbon storage in the rhizosphere and surrounding soil. This research leverages BER's fundamental microbial systems biology research in Genomics: GTL and BER's terrestrial carbon cycle research to evaluate options for molecular-based terrestrial carbon sequestration and contributes to the President's Advanced Energy Initiative (AEI).

▪ **Genomics: GTL**	**87,902**	**135,319**	**154,754**
• **Genomics: GTL Foundational Research**	**64,502**	**65,319**	**39,754**

Genomics: GTL has the mission goal of developing the science, technology, and knowledge base to harness microbial and plant systems for cost-effective renewable energy production, carbon sequestration, and environmental remediation. The research program supports fundamental research and technology development that underpins all microbial and plant research conducted in the Genomics: GTL program overall and in the GTL Bioenergy Research Centers. GTL foundational research also develops the robust computational infrastructure needed to understand, predict and ultimately use the genomic potential, cellular responses, biological regulation, and behaviors of biological systems of interest to the DOE mission.

In FY 2008, the program continues to support a mix of approximately eight large multidisciplinary research teams and 30 smaller individual investigator projects to:

- develop innovative high-throughput genomic and analytic strategies and research tools for improving plant biomass and for the subsequent microbial conversion of plant biomass to biofuels, fundamental research that will contribute to GTL Bioenergy Research Centers and to GTL Bioethanol research;
- develop novel technologies to characterize the internal environment, subcellular architecture and metabolism of microbes, fundamental research that will contribute to GTL Bioenergy Research Centers and to GTL Bioethanol and Biohydrogen research; and

- develop genomic, metabolic and imaging technologies to study the structure and function of microbial communities with respect to fate and transport of environmental contaminants, bioenergy production and the fate and flow of carbon through terrestrial and marine environments.

This activity includes capital equipment support for the Genomics: GTL program that will provide state-of-the-art equipment and high performance instrumentation to meet the program's advanced imaging, high-throughput, and analytic requirements.

This activity will develop a computational infrastructure for Genomics: GTL research. The necessary algorithmic and computational tools will be developed to allow modeling of critical metabolic pathways in plants, microbes and microbial communities. Further, computational databases will be developed that have the capacity to integrate large and diverse data sets into a unified model that predicts the behavior of relevant biological systems. The research is closely coordinated with SC's Office of Advanced Scientific Computing Research and includes the GTL SciDAC research.

In FY 2008, increased GTL SciDAC research will initiate new research to develop mathematical and computational tools needed to model *in silico* genomic changes to plants and microbes. This new computational capability is expected to enable the more economical design, development and improvement of desirable properties of organisms to enable more efficient conversion of sunlight to biomass and biomass to biofuels as well as to better predict the earth's biological carbon cycle.

Over the long-term, the GTL Foundational Research should provide the scientific knowledge base and technology that can accelerate progress in all aspects of the Genomics: GTL program, as well as bridge to other DOE offices such as Energy Efficiency and Renewable Energy, Fossil Energy, and Environmental Management to develop biotechnology solutions for DOE energy and environmental needs. The program focuses 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.

The research is coordinated across DOE programs, both within and outside SC (BER, Basic Energy Sciences, and Energy Efficiency and Renewable Energy), across Federal Agencies, including the Department of Agriculture, the National Institutes of Health, the National Science Foundation, and across DOE laboratories, academia, industry, and non-governmental organizations.

The research activities are carried out at National laboratories, universities and private institutions and selected through competitive and merit-reviewed processes.

	FY 2006	FY 2007	FY 2008
• **Genomics: GTL Sequencing**	**10,900**	**10,000**	**10,000**

DNA sequence data underpins and is the starting point for all aspects of the Genomics: GTL program. The vast majority of high-throughput DNA sequencing of plants, microbes, and microbial communities conducted at the JGI/PGF user facility is directly relevant to the Genomics: GTL program. However, the Genomics: GTL program has some unique DNA sequencing needs and challenges. In FY 2008, research will continue within Genomics: GTL to

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

generate DNA sequence data of cDNA expression, whole genomes and metagenomes in order to provide essential information needed to formulate genetic engineering strategies for microbes and plants, to understand plant and microbe molecular machines, to determine the composition of complex microbial communities, and to dissect plant-microbe associations. The DNA sequencing done in this sub-program complements the broader DNA sequencing activities conducted at the JGI/PGF and will specifically provide genetic data to projects within the Genomics: GTL program, including the Bioenergy Centers, and to sequencing projects that have a direct scientific impact on the Genomics: GTL program.

The research is coordinated across DOE programs (both within and outside SC), across federal agencies (including the Department of Agriculture, National Science Foundation, National Institutes of Health), and across DOE laboratories, academia, industry, and non-governmental organizations.

	FY 2006	FY 2007	FY 2008
• **Genomics: GTL Biohydrogen Research**	**12,500**	**20,000**	**15,000**

Genomics: GTL research will contribute to the President's Advanced Energy Initiative with biotechnology solutions for production of two biofuels: hydrogen and ethanol. Hydrogen is the ultimate carbon-free energy carrier that can be converted efficiently to energy in fuel cells with water as the only chemical by-product. Microbes exist that can use solar energy to convert water to hydrogen and oxygen, or to break down biomass and convert the component sugars into hydrogen.

This activity supports innovative systems biology research with a specific emphasis on biological hydrogen production, such as the discovery and development of improved or oxygen-tolerant hydrogenases, characterization of specific cellular architecture to facilitate electron transfer for optimum hydrogen production, and the redirection of metabolic pathways and metabolite flow into hydrogen production. While this activity draws upon the foundational research and technology development within the broader GTL portfolio, it is specifically directed towards scientific issues and challenges unique to biological hydrogen production.

FY 2008 funding is decreased in support of Genomics: GTL Bioenergy Research Centers.

The research is coordinated across DOE programs (both within and outside SC), across federal agencies (including the Department of Agriculture and National Science Foundation), and across DOE laboratories, academia, industry, and nongovernmental organizations.

	FY 2006	FY 2007	FY 2008
• **Genomics: GTL Bioethanol Research**	**—**	**20,000**	**15,000**

GTL research will contribute to the President's Advanced Energy Initiative with biotechnology solutions for two biofuels: ethanol and hydrogen. Cellulosic ethanol is a carbon-neutral fuel that can already be used within today's energy infrastructure. Microbes or microbial processes are used to produce ethanol from residues such as corn plants left after a corn harvest or energy crops such as poplar trees that are specifically grown as biomass for energy production.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

While this activity draws upon the foundational research and technology development within the broader GTL portfolio it is specifically directed towards scientific issues and challenges unique to understanding the metabolic conversion of 5- and 6-carbon sugars to ethanol. In FY 2008, research will support understanding of mechanisms that control glycolytic flux, analysis and rational design of more robust ethanolgenic biocatalysts, and discovery of biochemical approaches to improve produce tolerance to inhibition during ethanol production in hydrolysates.

FY 2008 funding is decreased in support of Genomic: GTL Bioenergy Research Centers.

The research is coordinated across DOE programs (both within and outside SC), across federal agencies (including the Department of Agriculture and National Science Foundation), and across DOE laboratories, academia, industry, and nongovernmental organizations.

	FY 2006	FY 2007	FY 2008
• **Genomics: GTL Bioenergy Research Centers**	**—**	**20,000**	**75,000**

GTL Bioenergy Research Centers will contribute to the President's Advanced Energy Initiative. The Research Centers will conduct fundamental biological research and involve no construction of facilities. The three Bioenergy Research Centers, potentially involving academic, industrial, and national lab scientists, are designed to accomplish the GTL program objectives more rapidly, more effectively, and at a reduced cost by concentrating appropriate technologies and scientific expertise to go from the genome sequence to an integrated systems understanding of the pathways and internal structures of plants and microbes most relevant to the steps required to develop bioenergy compounds. The first two GTL Bioenergy Research Centers are expected to be selected and initiated in late FY 2007 following the issuance of a competitive funding opportunity announcement on August 1, 2006 and site selection according to merit-based peer review criteria. In FY 2008, these two Bioenergy Centers are fully supported at roughly $25,000,000 each. A third GTL Bioenergy Research Center will be initiated in FY 2008 following site selection based upon merit-based peer review criteria.

Research at the Centers will focus on developing the science underpinning biofuel production that will ultimately lead to technology deployable in the Nation's energy economy. A major emphasis will be on development of cost-effective strategies to convert biomass to ethanol, and potentially, production of biodiesel, hydrogen, methane and biofuels for aviation. The Centers will draw heavily on technology and basic science generated in the foundational research, biohydrogen, and bioethanol Genomics: GTL activities. The research programs in the Centers will be distinguished from those sub-programs by being broader in scope. The research at the Centers will, potentially:

- encompass the entire spectrum from research on enhancing biomass generation and improving/modifying biomass feedstocks to biofuel production,
- pursue more high-risk, high-return approaches to bioenergy production,
- be more flexible in being able to incorporate new knowledge and change scientific direction, and
- be more problem oriented with respect to cost-effective biofuel production.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

The Centers will be held to both intermediate and long term scientific deliverables to ensure that they are to help meet the longer-term goals of the Advanced Energy Initiative.

▪ **Low Dose Radiation Research**	**17,006**	**17,496**	**17,581**

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 critical to adequately and appropriately protect people and to make the most effective use of our national resources. 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 the most cost-effective manner. Some research in this program is jointly funded with NASA's Office of Biological and Physical Research.

It remains a substantial challenge to resolve the scientific uncertainty surrounding the current use of the linear no-threshold (LNT) model for developing radiation protection standards at low doses of radiation.

In FY 2008, the program is also emphasizing the use of genome-based technologies to learn how cells communicate with each other in tissues in response to radiation, what causes cells and tissue to undergo different biological responses to radiation at different times, and how some people may be more sensitive to radiation while others are relatively resistant. Comparative genomics will afford new opportunities for identification of specific genetic markers within affected cell populations.

University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this activity.

Human Genome	**60,823**	**74,575**	**72,733**
▪ **Joint Genome Institute**	**51,500**	**62,055**	**60,000**

The Joint Genome Institute's (JGI) high-throughput DNA sequencing factory, the Production Genomics Facility (PGF) is focused on helping to meet the growing demand for DNA sequencing in the broader scientific community. Sequencing capacity will be increased 10% to approximately 60 billion base pairs in FY 2008 to support the increasing demand and need of the DOE research programs and the scientific community. The JGI's Community Sequencing Program (CSP) devotes all of its sequencing capacity to the merit-reviewed sequencing needs of the broader scientific community, while addressing the DOE mission-relevant criteria of energy production, carbon sequestration research and bioremediation research, and low dose radiation research.

In FY 2008, the CSP will sequence DNA from individual microbes, microbial communities, and small and large plants that will be selected by the CSP's merit review panel in FY 2007. The Laboratory Science Program is expected to be initiated in FY 2007 to expand participation in genomic-based research at the DOE national laboratories. Funds are provided to support DNA sequencing and DNA sequencing research that present unique sequencing challenges primarily attributable to the complexity or difficulty of the environments from which the microbes or plants were isolated, as well as to the increasing difficulty of assembly of highly repetitive complex plant genomes.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

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

▪ **Tools for DNA Sequencing and Sequence Analysis**	**7,723**	**10,520**	**7,733**

BER continues to develop the tools and resources needed by the scientific, medical, and industrial sector communities to fully exploit the information contained in complete DNA sequences, from energy-relevant microbes to low dose radiation effects. Use of sequence information to understand human biology and health effects will also require new strategies and tools capable of high-throughput, genome-wide experimental and analytic approaches. BER will continue efforts to develop high-throughput approaches for analyzing gene regulation and function.

In FY 2008, the continued funding will support additional efforts to develop high-throughput annotation methods that keep pace with the rapidly increasing rate of DNA sequencing.

▪ **Ethical, Legal, and Societal Issues (ELSI)**	**1,600**	**2,000**	**5,000**

BER ELSI research will continue the transition to activities applicable to Office of Science issues in bioenergy, synthetic biology, and nanotechnology, including exploration of, and communication of, the societal implications arising from these programs. The ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies will be studied. The research will be coordinated across the Office of Science and with other relevant Federal agencies and offices (e.g., EPA and OSTP).

In FY 2008, activities will include support for peer-reviewed research on intellectual property and commercialization issues, economic impacts of sustainable agriculture-based biofuels, including land-use patterns, biorefineries, public perceptions of synthetic biology and nanotechnology applications, and added support for activities exploring the societal implications of research to be carried out by and at the BES Nanoscience Centers. The increased funding will support research on the ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies.

Health Effects	**8,852**	**7,321**	**7,321**

Health effects research in functional genomics provides a link between human genomic sequencing and the development of information that is useful in understanding normal human development and disease processes including susceptibility to low doses of ionizing radiation. The mouse continues to be a useful experimental tool for this understanding. The Center for Comparative and Functional Genomics ("Mouse House") at Oak Ridge National Laboratory serves as a national focal point for high-throughput genetic studies using mice. The Mouse House 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 mice.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2008, research will continue at the Laboratory for Comparative and Functional Genomics related to low dose radiation. However, BER will no longer fund the Mouse House as a user facility. BER's programmatic need for this facility as a resource for understanding the human genome has ended with the completion of human genome related research and the growth of the GTL program. However, there is still a broad need for mouse genetic resources in the scientific community, especially at the National Institutes of Health.

The research activities are principally carried out at national laboratories, selected through merit-reviewed processes.

	FY 2006	FY 2007	FY 2008
SBIR/STTR	**—**	**7,020**	**7,527**

In FY 2006 $4,884,000 and $588,000 were transferred to the SBIR and STTR programs, respectively. FY 2007 and FY 2008 amounts are the estimated requirements for continuation of the programs.

	FY 2006	FY 2007	FY 2008
Total, Life Sciences	**197,695**	**264,158**	**282,343**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Molecular and Cellular Biology	
▪ Genomics: GTL Foundational Research will decrease to initiate funding for a third GTL Bioenergy Research Center and fully fund operation of the two bioenergy research centers expected to be initiated in FY 2007.	-25,565
▪ GTL Biohydrogen research decreases to support the Bioenergy Research Centers.	-5,000
▪ GTL Bioethanol research decreases to support the Bioenergy Research Centers.	-5,000
▪ Genomics: GTL Bioenergy Research Centers will increase to initiate funding for a third GTL Bioenergy Research Center and fully fund operation of the two bioenergy research centers expected to be initiated in FY 2007.	+55,000
▪ Low Dose Radiation Research is held near FY 2007 levels.	+85
Total, Molecular and Cellular Biology	**+19,520**
Human Genome	
▪ The Joint Genome Institute's (JGI) high-throughput DNA sequencing factory is decreased. However, because of advances in sequencing technology, the JGI DNA sequencing will increase at least 10 percent over FY 2007 levels.	-2,055
▪ Tools for DNA sequencing is decreased as the Human Genome Program has ended. The level of support will provide innovative tools and strategies for the scientific community to utilize and exploit rapidly expanding genomic data base.	-2,787

	FY 2008 vs. FY 2007 ($000)
▪ BER ELSI will initiate studies on the ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies.	+3,000
Total, Human Genome	**-1,842**
SBIR/STTR	
▪ Increases in SBIR/STTR due to increases in Life Sciences research funding.	+507
Total Funding Change, Life Sciences	**+18,185**

Climate Change Research

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Climate Change Research			
Climate Forcing	76,310	77,831	77,778
Climate Change Modeling	26,955	25,175	32,427
Climate Change Response	26,891	23,181	19,380
Climate Change Mitigation	6,474	5,014	4,747
SBIR/STTR	—	3,708	3,792
Total, Climate Change Research	136,630	134,909	138,124

Description

The mission of the Climate Change Research subprogram is to deliver relevant scientific knowledge that will enable both scientifically based predictions and assessments of the potential effects of greenhouse gas and aerosol emissions on climate and the environment, and the development of approaches for enhancing carbon sequestration in terrestrial ecosystems.

Benefits

This subprogram's research is expected to reduce and resolve key uncertainties and provide the scientific foundation needed to predict, assess, and help mitigate greenhouse gas forcing of climate resulting from energy production and use. Climate forcing research leads to understanding and quantification of natural and human-induced forcing of the climate system and the processes that affect such forcing, including the role of clouds, aerosols and carbon cycling. Climate change modeling research leads to the development, testing and application of fully coupled climate and Earth system models needed to project the likely response of the climate system to natural and human-induced climate forcing. Climate change response research leads to the understanding and ability to predict the response of ecological and human systems to ongoing and projected future changes in climate and atmospheric composition associated with energy production. Climate change mitigation research leads to the development of strategies or technologies for modifying or managing terrestrial systems to enhance their sequestration capacity.

Supporting Information

The Climate Change Research subprogram supports four contributing areas of research: Climate Forcing, including processes that affect climate forcing; Climate Change Modeling; Climate Change Responses; and Climate Change Mitigation. 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 changes in radiative forcing of climate resulting from energy production and use, primarily the emission of carbon dioxide and aerosols from fossil fuel combustion. It is also focused on how the climate system would likely respond to human-induced and natural changes in radiative forcing. The subprogram also includes research to understand and quantify the potential response of ecological systems to climatic changes. Lastly, it includes research to understand how natural processes in terrestrial ecosystems can be altered or managed to enhance their long-term capacity to sequester carbon dioxide emitted to the atmosphere, thereby helping to mitigate the increase in atmospheric CO_2. BER has designed and planned the research program to provide data that will enable objective assessments of the potential for, and consequences of, global warming. It is intended to provide a scientific basis that will enable decision makers to determine a “safe level” of greenhouse gases in the Earth’s atmosphere to avoid a disruptive, human-induced interference in the climate system.

U.S. Climate Change Research is currently organized into the Climate Change Science Program (CCSP) and the Climate Change Technology Program (CCTP). The CCSP includes the interagency U.S. Global Change Research Program (USGCRP), proposed by the first President Bush in 1989 and codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606), and the current Administration’s Climate Change Research Initiative (CCRI).

The BER Climate Change Research subprogram (excluding the Climate Change Mitigation element which focuses on carbon sequestration in the terrestrial biosphere) represents DOE’s contribution to the CCSP (USGCRP and CCRI). The Climate Change Mitigation element in Climate Change Research plus the carbon sequestration activity in the Life Sciences subprogram are BER’s contribution to the CCTP.

The CCRI is a set of cross-agency activities in areas of high priority climate change research where substantial progress is anticipated over the next two to four years. The specific focus areas include climate forcing (atmospheric concentrations of greenhouse gases and aerosols); climate observations, climate feedbacks and sensitivity; climate modeling, including enabling research; regional impacts of climate change, including environment-society interactions; and climate observations. In FY 2008, BER will continue to participate in specific research areas of the CCRI. These areas include climate forcing, which includes modeling carbon sources and sinks, especially those in North America and quantifying the magnitude and location of the North American carbon sink, a high priority need identified in the interagency Carbon Cycle Science Plan. In climate modeling, DOE’s contribution to the CCRI will continue to involve the production of future potential climate scenarios for use in assessing the environmental implications of different future possible climate states. In the climate observations area of the CCRI, the ARM mobile facility will be deployed to a location where data are needed to fill gaps in understanding key atmospheric properties and processes, and their effect on the Earth’s radiation balance and climate. The Integrated Assessment Research contribution to the CCRI will continue to be the development of tools for use in assessing the costs and benefits of human-induced climate change, including those associated with different policy options for mitigating such change. (BER’s FY 2008 CCRI request is $23,672,000).

Periodic retrospective analysis is employed to evaluate program management processes, priorities, and outcomes. A BERAC Committee of Visitors (COV) for the Climate Change Research Program was established in FY 2004 to provide outside expert validation of the program’s merit-based review and funding decision processes that impact scientific quality, programmatic relevance, and performance. The full report and the BER response are at http://www.science.doe.gov/ober/berac.html. The next COV for the Climate Change Research Program will be in FY 2007. The BERAC is also tasked to conduct reviews of specific programs. The most recent was a review of the Terrestrial Carbon Processes Program in FY 2006 by a subcommittee of BERAC. BERAC was also tasked to undertake a review of the Integrated Assessment Program in early FY 2007.

FY 2006 Accomplishments

Climate Forcing:

- **Multi-Scale Simulations of Clouds:** The Multi-scale Modeling Framework (MMF) is a recently developed approach to climate modeling, in which a two-dimensional cloud-resolving model (CRM) is embedded into each grid column of an Atmospheric General Climate Model (AGCM), replacing traditional cloud and radiation parameterizations. Two studies demonstrated improvements in climate simulations using the MMF. The first showed that a model using the MMF produces a simulation of upper tropospheric cloudiness that is much more realistic than a control run from a model without the MMF. The second study compared model simulations with observations from two of the ARM sites. The simulations included a run using the MMF as well as a run with traditional or standard cloud and radiation treatments. Time series of cloud fraction, precipitation intensity, and downwelling solar radiation flux at the surface were analyzed. The distributions of these variables from the MMF run were found to be more consistent with observations from the Tropical Western Pacific ARM site than those from the run using the standard cloud and radiation treatments. This change is attributed to the improved representation of convective clouds in the MMF compared to the conventional climate model which contained a standard representation of clouds. For the Southern Great Plains site, use of the MMF approach showed little or no improvement in predicting the same quantities, suggesting that standard cloud and radiation parameterization schemes may be sufficiently reliable for modeling the cloud properties and processes and their interactions with radiation for some but not all climatic regions of the globe.

- **Modeling Study Shows Important Role of Isoprene as Precursor of Secondary Organic Aerosol:** A major puzzle in recent field measurements has been a much greater abundance of organic aerosols than had been expected based on chemical modeling of previously known sources of these aerosols. A recent study which included isoprene as a source of secondary organic aerosol (SOA) in a global aerosol model found that the global burden of SOA from all sources was increased by more than a factor of two. The isoprene source substantially increases SOA concentrations in the free troposphere, because isoprene, and, more importantly, its oxidation products, exhibit much greater concentrations at higher altitudes than other biogenic SOA precursors, highlighting the role of semi-volatile organics for SOA formation. This additional source of SOA enhances production of SOA from other parent hydrocarbons by 17%, and leads to an overall distribution of SOA that differs enough from previous predictions to warrant reevaluation of the radiative effects of organic carbon aerosol.
- **Net Ecosystem Exchange of Carbon Dioxide for Different Vegetation Types:** The effect of different vegetation types on net ecosystem exchange (NEE) of carbon dioxide between the atmosphere and terrestrial biosphere was determined from AmeriFlux Network sites in close proximity. Five years of NEE measurement showed that average annual NEE values of three vegetation types were 4.4, 4.5, and 0.09 tonnes of carbon per hectare for mature and mostly deciduous forest, young pine, and old-field (mostly grass) stands, respectively. These measures represent annual net carbon gain by vegetation types that are typical of those across the uplands of the Southeastern United States. Contrary to some notions, these observations indicate that mean annual NEE of the mature forest is not significantly different from that of a 35 year old plantation (i.e., 4.4 vs 4.5 tonnes). Year-to-year response to variation in precipitation was much greater in the pine plantation than in the other vegetation types; NEE of the plantation stand increased 33% in a wet year and decreased by 21% in a dry year compared to the 5-year average, while the hardwood stand showed little year-to-year variability in the NEE measure. These multi-year AmeriFlux observations for climate variations over the 5-year period provide robust data for isolating vegetation influences on terrestrial carbon budgets of terrestrial ecosystems.

Climate Change Modeling:

- **Estimated Climate Sensitivity Constrained by Temperature Reconstructions Over the Past Seven Centuries:** The magnitude and impact of future global climate change depends on the sensitivity of the climate system to changes in greenhouse gas concentrations. The commonly accepted range for the equilibrium global mean temperature change in response to a doubling of the atmospheric carbon dioxide concentration, termed climate sensitivity, is 1.5 to 4.5^{o} C. A number of observational studies, however, find a substantial probability of significantly higher sensitivities, yielding upper limits on climate sensitivity of 7.7^{o} C to above 9^{o} C. DOE-sponsored researchers demonstrated that observational estimates of climate sensitivity can be tightened if reconstructions of Northern Hemisphere temperature over the past several centuries are considered. Using large-ensemble energy balance modeling to simulate the temperature response to past solar, volcanic and greenhouse gas forcing, the climate sensitivities which yield simulations that are in agreement with proxy reconstructions were determined. After accounting for the uncertainty in reconstructions and estimates of past external forcing, an independent estimate of climate sensitivity was determined that is very similar to those from instrumental data. When the latter are combined with the result from all proxy reconstructions, the 5% to 95% range of climate sensitivity shrinks to 1.5^{o} to 6.2^{o} C, thus substantially reducing the probability of very high climate sensitivity to a doubling of the concentration of atmospheric dioxide.

Climate Change Response:

- **Counteracting Effects of Rising Atmospheric CO_2 and Ozone Concentrations on Tree Growth:** Research at a Free-Air Carbon dioxide (CO_2) Enrichment (FACE) facility near Rhinelander, Wisconsin, is determining possible effects of rising concentrations of CO_2 and ozone (O_3) in the lower atmosphere on the growth (accumulated living biomass) of northern hardwood tree stands. After six years of treatments using concentrations of O_3 projected for the year 2050 (i.e., 50% greater than today), total biomass of aspen stands, aspen-birch mixtures, and aspen-maple mixtures, was reduced 23%, 13%, and 14%, respectively relative to that in control stands exposed to current ambient concentrations of O_3. When exposed to both elevated O_3 and CO_2 concentrations, the latter also projected for the year 2050 (i.e., 560 ppm), the aspen biomass was only 8% lower compared to that in stands of aspen growing in the present ambient atmosphere. Moreover, the accumulated biomass of the aspen-birch and aspen-maple mixtures was stimulated (8% and 24%, respectively) by the combination of elevated CO_2 and elevated O_3 relative to the present ambient atmosphere. The results amplify the importance of studying the combined effect of multiple changes in the environment rather than the effect of only single (isolated) factors, and indicate the importance of species-specific effects of environmental change.

Climate Change Mitigation:

- **Elevated Atmospheric CO_2 Increases Soil Carbon:** Carbon accrual in soil was determined from FACE and other CO_2 experiments of 2-9 year duration. In these field studies, the carbon dioxide enrichment is roughly double pre-industrial atmospheric levels (or 50% greater than today's ambient concentration), and both plant growth and productivity are stimulated, resulting in large increases of root mass and litter. For these conditions the overall soil carbon content increased by 5.6%, and at a rate of 0.19 megagrams of carbon per hectare per year. Over half of the accrued carbon was incorporated into microaggregates, which can protect carbon from rapid decomposition and increase its potential residence time in the soil. These findings indicate that the carbon storage capacities of many soils—including some with large organic matter stocks—may not be saturated at present and might be capable of serving as carbon sinks if detrital inputs increase as a result of passive CO_2 fertilization or active management efforts to sequester carbon.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Climate Forcing	**76,310**	**77,831**	**77,778**
▪ **Atmospheric Radiation Measurement (ARM) Research**	**14,714**	**14,765**	**14,765**

A major emphasis in the Climate Forcing area 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 this balance is affected by clouds, aerosols, and changes in increases in the concentration of greenhouse gases in the atmosphere. This area also includes research to understand the processes in the terrestrial biosphere that affect the exchange of carbon dioxide between the terrestrial biosphere and atmosphere and to quantify their net effect on atmospheric concentrations of carbon dioxide so as to better understand how they might affect atmospheric concentrations and climate forcing in the future.

Research in the 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. An important element of this research is on developing component process models (e.g., cloud resolving and aerosol process models) and parameterization schemes of processes that affect climate forcing so they can be included and tested in climate models. In FY 2008, the principal goal of the ARM research will continue to be the development of an improved understanding of the radiative transfer processes in the atmosphere and to formulate better parameterization schemes of these processes in climate prediction models, referred to as General Circulation Models (GCMs). The funding will support research using ARM data to develop and test cloud resolving models and other parameterization schemes and incorporate them in cloud modeling approaches such as the Multi-scale Modeling Framework. The cloud modeling approaches will then be incorporated in Atmospheric General Circulation Models to test and intercompare their performance in improving climate simulations.

ARM research supports investigators at universities and DOE laboratories involved in studies of cloud physics and the interactions of solar and infrared radiation with water vapor, clouds, and aerosols (including black soot). University scientists form the core of the ARM science team that networks with the broader academic community, including scientists funded by NSF. Networking also occurs 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 to the production of ARM data, e.g., as designers of new remote sensing instrumentation for use at ARM sites, the development and application of methods to process ARM data, and produce data sets useful to researchers, as well as consumers of the data generated at the three stationary ARM sites and the mobile ARM facility. To facilitate the knowledge transfer from the ARM program to the premier modeling centers, the ARM program also supports scientific "Fellows" at NSF's National Center for Atmospheric Research, NOAA's National Center for Environmental Prediction, and the European Center for Medium-Range Weather Forecasting. In addition, the model parameterization test bed implemented at Lawrence Livermore National Laboratory will be

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

continued to enable the testing and improvement of parameterization schemes and 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.

	FY 2006	FY 2007	FY 2008
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**	**33,795**	**35,174**	**35,150**

In FY 2008, the ARM infrastructure will continue to support and maintain the operation of three stationary ARM facilities and associated ground-based instrumentation ($24,903,000). It will also support the maintenance, upgrading and deployment of the ARM mobile facility ($5,000,000). It will continue to support application of ARM Aerial Vehicles for use in field campaigns around the ARM facilities and at sites of opportunity where measurement campaigns are conducted to obtain data on clouds and atmospheric properties and processes at different altitudes ($2,733,000). The ARM Infrastructure program will continue to provide data to the scientific community through the ARM Archive ($2,514,000).

The ARM data streams will continue to be enhanced periodically by additional measurements at the ARM facilities during intensive field campaigns referred to as Intensive Operational Periods (IOPs). Selection of proposed IOPs for implementation is based on a solicitation for proposals and a competitive merit review. Ranging from two weeks to two months, the campaigns bring together teams of scientists to coordinate measurements with airborne and satellite observations to measure particular processes and their effects on radiation around one of the facilities. These IOPs often involve coordinating the ground-based measurements with airborne and satellite observations. The ARM facilities are major testbeds of research on atmospheric processes, serving as scientific user facilities for hundreds of scientists from universities and government laboratories. Both NASA and DOD, for example, use the ARM facilities to “ground truth” measurements made with some of their satellite-based instruments. The ARM program, including the ARM Aerial Vehicles program (AAVP), will conduct a major field campaign focusing on the interactions between the land surface and the life cycle of clouds. The CCRI ARM program will continue to deploy an ARM mobile facility in selected locations that are either data poor or represent locations of opportunity for measuring effects of atmospheric conditions on the radiation balance that are currently poorly understood (e.g., direct and indirect effects of aerosols and their interactions with clouds). The primary criterion for deployment of the mobile facility is to provide needed measurements to address specific modeling needs that cannot be provided by measurements from the stationary ARM facilities. The deployment location for the ARM mobile facility and the scientific focus and location of ARM IOPs in FY 2008 have not yet been determined, but a decision is expected following the review of proposals that are solicited from the research community.

The research activities are carried out at national laboratories, universities, and private institutions, and are selected through competitive, merit review processes.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **Atmospheric Science**	**12,794**	**12,551**	**12,551**

The entire Atmospheric Science Program is focused on research dealing with aerosol properties and processes and their effect on radiation and climate. The focus of this program is on acquiring the data needed to understand the atmospheric processes that control the transport, transformation, and fate of energy-related aerosols emitted to the atmosphere and their radiative properties so as to enable more reliable and accurate simulations of their effect on climate.

In FY 2008, the Atmospheric Science Program (ASP) will continue to characterize the physical, chemical, and optical properties of energy-related aerosols and their direct and indirect effects on radiation and climate. This will include laboratory studies and field research to understand aerosol formation and transformation processes and their effect on aerosol radiative properties, including the indirect effect on cloud properties and processes. Acquired data will be used to develop and test predictive parameterization schemes or models for aerosol properties and their effect on radiative transfer in the atmosphere. The ASP will also continue supporting the development of new instruments for measuring aerosol properties and processes of importance to climate. The ASP aerosol research will continue to be closely coupled and coordinated with other components of DOE's climate change research, especially the ARM and climate modeling programs by conducting joint field campaigns with the ARM program and providing aerosol process models for testing in climate models. The ASP will continue to be broadly coordinated with the climate change research in other agencies, including collaborations with NOAA, NASA, NSF, and EPA, and with the DOE Office of Fossil Energy's Airborne Fine Particulate Matter (PM) Research program. Much of the research will involve multi-agency collaboration, and university scientists will play key roles. The information is essential for improving the scientific basis for assessing the effects of energy-related emissions on climate and will contribute to the evaluation of science-base options for minimizing the impacts of energy production on climate change.

The ASP will conduct a major collaborative field campaign in FY 2008 ($2,000,000) aimed at measuring interactions of aerosols with clouds in a region that is not well simulated by current climate models, and monitoring changes in these interactions for regional aerosols of differing physical and chemical properties. The location of this campaign is not yet finalized. Data from this and other field campaigns sponsored by the ASP will be analyzed and results will be aimed at measuring interactions of aerosols with clouds in a region that is not well simulated by current climate models, and monitoring changes in these interactions for regional aerosols of differing physical and chemical properties.

Research activities are carried out by scientists at national laboratories, universities and private institutions and are selected through competitive and merit-review processes.

▪ **Terrestrial Carbon Processes**	**10,444**	**13,332**	**13,439**

In FY 2008, BER will continue support of AmeriFlux, a network of research sites where the net exchange of carbon dioxide, energy, and water between the atmosphere and major terrestrial ecosystems in North America is continuously measured. Approximately 25 of the sites are funded by BER at an average of $200,000 each, along with the quality assurance of the measurements and data, and the data archiving to make it available to the broader scientific community. There are approximately 75 additional sites in the AmeriFlux network that are funded by other agencies

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

(NASA, NOAA, United States Geological Service (USGS), Forest Service, and Agriculture Research Service). The AmeriFlux measurements are linked to field measurement campaigns across major regions of North America that are designed to test how well point measurements of fluxes represent fluxes observed over larger areas within the same region and allow the estimate of carbon sources and sinks on a regional and eventually a national or continental basis.

In FY 2008, three of the four free-air carbon dioxide enrichment (FACE) experiments, previously funded as FACE user facilities, will be funded as part of the Terrestrial Carbon Processes research activity for approximately $4,500,000. These are the three sites located in Nevada, North Carolina, and Tennessee. Support for the fourth (Rhinelander, Wisconsin) will be provided by the Ecosystem Function and Response research activity. The focus of the FACE experiments funded by the Terrestrial Carbon Processes Program is on the capacity of the ecosystems to capture and store carbon when exposed to an elevated concentration of carbon dioxide.

The research supports the interagency Carbon Cycle Science Plan which is focused in the near term on the North American Carbon Plan that is designed to quantify the magnitude and location of the North American carbon sink. In FY 2008, BER's terrestrial carbon cycle research, as a partner in the interagency North American Carbon Program (NACP) will provide data, modeling, and analysis products from field measurements and campaigns. Data on net exchange of carbon dioxide will be produced by the AmeriFlux Network sites, and these data along with information from research on fundamental mechanisms and processes will help in testing remote sensing observations and model calculations of terrestrial sources and sinks of carbon for specific regions of North America.

BER will also continue research to refine and test terrestrial carbon cycle models based on mechanistic representation of important carbon cycle processes and carbon accounting. The models will be used to estimate the magnitude of potential carbon sinks and sources in response to changes in environmental factors, including climate variation. A major emphasis in FY 2008 will be on the development of a framework for simulating the cycling of carbon at subcontinental and continental scales that span a wide diversity of bioclimatic conditions, ecosystem types and land use.

Research activities are carried out at national laboratories, universities, and private institutions and are selected through competitive and merit-review processes.

▪ **Ocean Sciences**	**2,696**	**136**	**—**

Ocean sciences research is concluded. DOE has met its commitment to the scientific community to support the analysis of ocean carbon data.

▪ **Information and Integration**	**1,867**	**1,873**	**1,873**

The Information and Integration element of Climate Forcing research will continue to store, evaluate, quality assure and disseminate a broad range of climate change related data, especially data on atmospheric concentrations and industrial emissions of greenhouse gases, greenhouse gas fluxes from terrestrial systems, ocean pCO_2 data, and air quality data. Archiving, management, and dissemination of ocean carbon data will continue. Disseminating data on greenhouse gases to the climate change research community for use in assessing changes in climate forcing due to increasing concentrations and emissions of greenhouse gases, for example, is an important function served by the Information and Integration element of BER's Climate Forcing research. The Carbon Dioxide

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Information and Analysis Center funded through BER's Information and Integration element, for example, is recognized as a World Data Center for accessing information on greenhouse gas emissions and concentrations. The Center serves a diverse set of users, including academic and laboratory scientists and policy makers globally. BER will also continue the Quality Systems Science Center for the tri-lateral (US, Mexico, Canada) NARSTO (formerly known as the North American Strategy for Tropospheric Ozone), a public partnership for atmospheric research in support of both air quality management and research on the effects of air quality on climate forcing and climate change. This Center also serves a diverse set of users, especially across North America, including both scientists and policy makers.

Climate Change Modeling	**26,955**	**25,175**	**32,427**

BER will continue to develop, improve, evaluate, and apply state-of-the-science coupled atmosphere-ocean-land-sea ice models (GCMs) that simulate climate variability and change over decade to centennial time scales. The goal is to achieve understanding of regional climate variability and change on scales as small as river basins, based on ensemble simulations. The ensemble simulations will accurately incorporate dynamic and thermodynamic feedback processes that influence climate, including clouds, aerosols, and greenhouse gas forcing. Current predictions and projections are limited by 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 continue to address both the computational and scientific shortcomings through an integrated effort. Support will continue to provide climate simulations using models that are being improved and develop new innovative models for use in the future. Support will continue to provide climate modelers access to the high-end computational resources needed to complete ensembles of climate simulations for modeling experiments using current and the future climate models. BER will emphasize research to develop and employ enabling technologies that can efficiently work with large and distributed data sets of both observations and model output to produce quantitative information suitable for studies and assessments of climate change at regional to global scales.

In FY 2008, BER researchers will examine specific model-based scenarios of future potential climate change to different natural and human-induced climate forcing scenarios. New research will be initiated to address strategic questions in abrupt climate change (approximately $3,800,000). The Climate Variability and Change Interagency Working Group of the U.S. Climate Change Science Program has identified Abrupt Climate Change as a priority focus area for FY 2008. The research will undertake the following: understanding the thresholds and nonlinearities in the climate system with a focus on mechanisms of abrupt climate change, incorporating mechanisms into coupled climate models, and testing the models vis-à-vis records of past abrupt climate change. DOE's focus on Abrupt Climate Change Modeling will be attribution of past abrupt climate change, and potential future abrupt climate change based on climate projections using a model that includes different mechanisms that have been hypothesized as causes of abrupt climatic change.

The model projections generated for the IPCC fourth Assessment Report will be further analyzed to assess how well they simulate climate dynamics and historic climate patterns and trends, including interannual climate variability and abrupt climate changes. These activities will be essential for understanding the state-of-the-science of U.S. climate modeling and uncertainties in simulating future climatic changes. BER will also continue to provide the infrastructure for evaluating the performance of major climate models and defining what changes may be needed to improve their performance. This will be done through continued support and coordination of model-data intercomparisons, the development and improvement of diagnostic tools for evaluating model performance, and the maintenance of test beds for evaluating model parameterizations. A Climate Change Science Program Synthesis and Assessment report on the evaluation of climate models for the historic period 1880-2000 will be completed, under the auspices of a DOE Federal Advisory Committee, as part of DOE's commitment to the U.S. Climate Change Science Program.

In FY 2008, BER's SciDAC for Climate Change Research ($7,776,000) will continue partnerships with the Advanced Scientific Computing Research program that were initiated under the 2006 SciDAC-2 competition. This will include work towards the creation of a first-generation Earth System model based on the Community Climate System Model that treats the coupling between the physical, chemical, and biogeochemical processes in the climate system. The model will include comprehensive treatments of the processes governing well-mixed greenhouse gases, natural and anthropogenic aerosols, the aerosol indirect effect and troposhpheric ozone for climate change studies. It also includes research to develop and test a global cloud resolving model using a geodesic grid, with grid-cell spacing of approximately 3 km, capable of simulating the circulation associated with large convective clouds. The SciDAC university grants program will be recompeted in FY 2007, and meritorious projects that address issues related to climate model development, e.g., the development of new innovative dynamical cores such as stretched grid or adaptive grid will be sponsored.

The research activities are carried out at national laboratories, universities, and private institutions and are selected through competitive and merit-review processes.

	FY 2006	FY 2007	FY 2008
Climate Change Response	**26,891**	**23,181**	**19,380**
▪ **Ecosystem Function and Response**	**14,884**	**11,583**	**13,182**

The goal of the Ecosystem Function and Response research subprogram will continue to be the reduction of important scientific uncertainties about potential effects of climatic change on the structure and functioning of important terrestrial ecosystems in North America. The FY 2008 focus will be on understanding the biological mechanisms responsible for potential changes in the structure and functioning of ecosystems caused by climatic changes. Critical topics that will be studied include: (a) effects of warming on northern forests; (b) effects of altered precipitation timing and amount on western ecosystems, including woodlands, forests, grasslands, and shrublands; (c) effects of changes in atmospheric composition (i.e., increases in both carbon dioxide and ozone concentrations) on interactions between primary producers and consumers in forest ecosystems; (d) interacting effects of rising carbon dioxide concentration and warming on the structure and functioning of model grassland ecosystems; and (e) effects of sea level rise and increased intensity of coastal storms on coastal ecosystems. New research projects will be initiated in FY 2008 based on results of a planned competition in 2007. Both manipulative experiments and process modeling will be used in the subprogram's research.

Research in FY 2008 will also continue to highlight quantitatively important linkages between different levels of biological organization in ecosystems. In particular, experiments will continue with the aim of unraveling linkages between proteomes of individual species and key processes occurring at the level of whole ecosystems. The focus will be on understanding the responses of

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

ecological systems to climatic and atmospheric changes as they are mediated by changes in the genomes or proteomes of plants and microorganisms in those ecosystems. Genetic limitations placed on the ability of organisms, communities, and ecosystems to migrate in response to climatic changes will also be studied. The latter topic will be critical to understanding how ecological processes might be affected by climatic change at the scale of landscapes and regions.

In FY 2008, the subprogram will continue to support the operation and maintenance of the free-air carbon dioxide enrichment (FACE) experimental infrastructure near Rhinelander, Wisconsin (approximately $1,700,000). This unique field experiment, previously funded as a FACE user facility, is enriching the atmosphere within constructed forest communities with carbon dioxide and ozone. It is being used to answer important questions about how changes in atmospheric composition associated with energy production, i.e., increasing atmospheric concentrations of carbon dioxide and ozone in the troposphere might directly affect the biological and ecological structure and functioning of a northern hardwood forests in the United States and elsewhere. The focus of this FACE experiment is on ecosystem response to the individual and combined effect of elevated ozone and carbon dioxide concentrations, whereas the focus of the FACE experiments funded by the Terrestrial Carbon Processes Program is on the capacity of the ecosystems to capture and store carbon when exposed to an elevated concentration of carbon dioxide.

New data and understanding obtained through the research funded by this subprogram will foster informed decision making about the uses of and the means of producing energy needed by society. It will do this by defining relationships between environmental changes caused by energy production and the potential effects of those environmental changes on the delivery of important goods and services provided by terrestrial ecosystems. Tools and principles developed from this research are expected to have broad generality and eventual application to problems in ecological risk assessment, carbon sequestration, and early detection of effects of climatic and atmospheric changes on ecological systems.

The research activities are carried out at national laboratories, universities, and private research institutions and are selected through a competitive, merit-review process.

▪ **Free Air Carbon Dioxide Enrichment (FACE) Facility**	**5,638**	**5,400**	**—**

In FY 2008, support for the conduct of FACE experiments will not be funded as user facility operations but instead as distinct experiments at the existing FACE sites in Wisconsin, Nevada, North Carolina, and Tennessee. Support for one of the FACE experiments will be provided by the Ecosystem Function and Response subprogram and three will be supported by the Terrestrial Carbon Processes subprogram. The activity is best characterized as field experiments in which multiple investigators jointly participate as collaborators to understand the direct effect of elevated carbon dioxide and other trace gases on terrestrial ecosystems rather than as a user facility.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **Integrated Assessment**	**4,948**	**4,772**	**4,772**

In FY 2008, the Integrated Assessment Program, with a strong academic involvement, will continue to support research to improve methods and models that can provide better estimates of the costs and benefits of global climate change and of possible actions to mitigate such change. The goal is to improve the integrated assessment models to include several greenhouse gases, including non-carbon based gases, such as nitrous oxide and ozone. An increased emphasis in FY 2008 will be on developing an ability to analyze various policy options for mitigating greenhouse gas emissions especially relevant to a post-Kyoto timeframe (after 2012), such as inducements to participate by lesser developed countries through financial and technology transfer incentives. Development of a capability to analyze the costs and benefits of alternative technology options will remain a priority. Particular emphasis will be on the representation of biologically-derived transportation fuels, such as cellulosic ethanol, and the ancillary effects on agriculture, land and water use, and international trade. Emphasis will continue on the development and analysis of the implications of long-term emission scenarios, such as the greenhouse gas stabilization scenarios presented in the CCSP Synthesis and Assessment report on emission scenarios that is being prepared by DOE as a Synthesis and Assessment Report for the U.S. Climate Change Science Program.

The research activities are carried out at national laboratories and universities and are selected through a competitive, merit-review process.

▪ **Education**	**1,421**	**1,426**	**1,426**

BER's Global Change Education Program will continue to support both undergraduate and graduate studies in FY 2008 through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREF). The GREF and the SURE provide a total of 45 students with support to conduct research that is of interest to them and relevant to DOE's climate change research. Their research is conducted under a mentor of their choice at either a university or a DOE laboratory. Funding for GREF and SURE only supports the students, not the mentor under which they each choose to work. The SURE continues to be a magnet for highly qualified undergraduates, most of who go to graduate school to study in fields directly related to what they did under SURE. Similarly students in the GREF program have received graduate degrees and many have stayed in the field and initiated their own research related to climate change.

Climate Change Mitigation	**6,474**	**5,014**	**4,747**

Ocean carbon sequestration research concluded in FY 2006, due to adverse effects (e.g., mortality of invertebrates in the deep ocean) on deep ocean biology and chemistry of injecting a relatively pure stream of carbon dioxide into the deep ocean as a possible strategy for sequestering carbon dioxide separated from fossil fuel power plants and industrial stack gases.

In FY 2008, BER's carbon sequestration research, part of BER's support to the Climate Change Technology Program, will focus only on terrestrial carbon sequestration. Research will continue on studies to enhance long-term sequestration processes and the stability of stored carbon in terrestrial vegetation and soils. The research focuses on understanding mechanisms controlling rates and capacities of soil carbon accretion of plant-soil systems, and how biological processes can be

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

manipulated in terms of allocating more carbon to the plant rhizosphere, and how to understand the properties of micro-biological systems that transform plant lignocellulose compounds into long-lived humic components of soil organic matter. The research addresses the effects of chemical manipulations to understand the role of calcium and nitrogen amendments on formation and stability of humic compounds in soil, including complexation of organic matter by iron oxide and other soil minerals that can potentially be purposefully altered to enhance carbon sequestration of terrestrial ecosystems. It will also continue to support research needed to understand and assess the potential environmental implications of purposeful enhancement of carbon sequestration in terrestrial ecosystems.

SBIR/STTR	**—**	**3,708**	**3,792**

In FY 2006, $3,508,000 and $419,000 were transferred to the SBIR and STTR programs, respectively. FY 2007 and FY 2008 amounts are the estimated requirements for continuation of the programs.

Total, Climate Change Research	**136,630**	**134,909**	**138,124**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Climate Forcing	
▪ The ARM infrastructure remains at near FY 2007 levels.	-24
▪ Terrestrial Carbon Processes remains at near FY 2007 levels.	+107
▪ Ocean Sciences research is concluded and phased out in FY 2007.	-136
Total, Climate Forcing	**-53**
Climate Change Modeling	
▪ Climate Modeling increases to accelerate research to create a first-generation Earth System model that is based on the Community Climate System Model. The Earth System model will treat the coupling between the physical, chemical, and biogeochemical processes in the climate system and allow modeling experiments to be conducted to investigate the interactions and feedbacks between the processes. The model will include comprehensive treatments of the processes governing well-mixed greenhouse gases, natural and anthropogenic aerosols, the aerosol indirect effect and tropospheric ozone for climate change studies. Furthermore, increased funding of approximately $3,800,000 will include the following: understanding the thresholds and nonlinearities in the climate system with a focus on mechanisms of abrupt climate change, incorporating mechanisms into coupled climate models, and testing the models vis-à-vis records of past abrupt climate change.	+7,252

	FY 2008 vs. FY 2007 ($000)
Climate Change Response	
▪ Ecosystem Function and Response increases to support the operational costs of an ongoing FACE experiment at Rhinelander, Wisconsin. The costs for this experiment were previously funded as part of a national user facility. In FY 2008, these costs will be funded as a research activity rather than as a national user facility.	+1,599
▪ FACE user experiments to study the direct effect of elevated carbon dioxide and other trace gases on terrestrial ecosystems will no longer be funded as user facilities. Research costs are included in Terrestrial Carbon Processes Research and Ecosystem Function and Response Research.	-5,400
Total, Climate Change Response	**-3,801**
Climate Change Mitigation	
▪ Carbon Sequestration research decreases—Ocean Carbon Sequestration research is concluded.	-267
SBIR/STTR	
▪ SBIR/STTR increases due to research program increases.	+84
Total Funding Change, Climate Change Research	**+3,215**

Environmental Remediation

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Environmental Remediation			
Environmental Remediation Sciences Research	52,171	50,479	52,339
Facility Operations	39,019	44,453	42,691
SBIR/STTR	—	2,264	2,400
Total, Environmental Remediation	91,190	97,196	97,430

Description

The mission of the Environmental Remediation Sciences subprogram is to deliver the scientific knowledge, technology, and enabling discoveries in biological and environmental research needed to underpin the Department of Energy's environmental stewardship mission.

Benefits

The fundamental research supported in this subprogram are expected to reduce the costs, risks, and schedules associated with the cleanup and monitoring of the DOE nuclear weapons complex; discover the fundamental mechanisms of contaminant transport in the environment; extend the frontiers of methods for remediation; and develop cutting edge molecular tools for investigating and monitoring environmental processes. This research also will provide fundamental knowledge that applies to a broad range of remediation problems, including avoidance of environmental hazards for future nuclear energy options. The research is already bridging the gap from basic research to application for other DOE offices. New, research-based, environmental remediation strategies and characterization tools are being deployed by the offices of Environmental Management and Legacy Management.

Supporting Information

Research goals for the Environmental Remediation Sciences subprogram include defining and understanding the processes that control contaminant fate and transport in the environment; providing opportunities for the use, or manipulation of natural processes to alter contaminant mobility and developing tools to accomplish those goals. Research results should help to provide the scientific foundation for the solution of key environmental challenges within DOE's cleanup mission at scales ranging from molecular to the field, including issues of fate and transport of contaminants in the environment; novel strategies for *in situ* remediation; and long-term monitoring of remediation strategies. The subprogram is closely integrated with the DOE offices of Environmental Management and Legacy Management. The goal of this integration is to provide basic research that supports the environmental remediation missions of these two offices and to optimize opportunities for the transfer of scientific advances to these offices' programmatic applications. The subprogram also is responsible for operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). This national user facility provides advanced molecular tools to the scientific community to address critical environmental issues including: environmental remediation, contaminant fate and transport in the environment, biology and genomics applications in the environment, atmospheric science and physical chemistry.

Within the subprogram, the Environmental Remediation Sciences research activity is increased to provide support for two additional field research sites (for a total of 3) and to support SciDAC research projects; the EMSL budget is increased to maintain operations at full capacity.

The Environmental Remediation Sciences subprogram research activities were integrated in FY 2006 based on recommendations of a BERAC Committee of Visitors (COV) review. The COV report was supportive of the subprogram and its approach to selecting and funding research projects. The COV found that Environmental Remediation Sciences activities were well-focused on the key science needs for DOE clean-up. The COV supported previous recommendations to expand opportunities for field-based research within the subprogram. This program will again host a COV in FY 2008.

The Environmental Remediation Sciences subprogram will develop a fundamental understanding of biological, chemical and physical phenomena across a range of scales up to and including the field scale. The resulting knowledge and technology will assist DOE's environmental cleanup and stewardship missions by developing: a more comprehensive understanding of contaminant fate and transport, *in situ* remediation technologies, subsurface characterization techniques, and performance monitoring of remedial technologies. This will be accomplished by soliciting and funding a range of projects from lab-based, single investigator research to complex, multidisciplinary, large-scale research projects that evaluate processes relevant to the environment at the field scale. This broad-based, tiered approach responds to the recommendations of the BERAC Environmental Remediation Sciences subcommittee and the COV review. The research program is designed to respond to the BER long-term environmental remediation measure "…to provide sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes into decision making for environmental remediation and long-term stewardship."

Periodic retrospective analysis will be employed to evaluate research directions, the accumulation of knowledge and to validate specific outcomes.

FY 2006 Accomplishments

- **Uranium can be Sequestered in Common and Unusual Subsurface Minerals:** Scientists from PNNL as well as the DOE/NSF collaborative Environmental Molecular Sciences Institutes report laboratory-based research on subsurface materials indicating that radionuclides such as uranium can be adsorbed and sequestered by a variety of common subsurface minerals including calcite, gibbsite, ferrihydrite and quartz in addition to forming unusual minerals such as sodium boltwoodite within the pores of subsurface materials. The results are important for developing more accurate models of the long-term sources and transport behavior of subsurface radionuclide contaminants at DOE sites such as Hanford, Oak Ridge and Uranium Mill Tailings Remedial Action (UMTRA) sites.
- **Whole Genome Analysis of Microorganisms at the Oak Ridge Field Research Center:** Researchers from multiple collaborating national laboratories and universities working at the Oak Ridge Field Research Center employed GTL-derived whole genome analysis of subsurface microbial communities involved in stimulated bioreduction of metals and radionuclides. The results will serve as a library of the genetic potential of organisms found in the subsurface and a basis for linking gene expression with the variable geochemical conditions found in the subsurface at this site. Assessing and linking the activity of microorganisms with the key biogeochemical processes controlling contaminant transport in the subsurface at DOE sites remains a priority.
- **Environmental Molecular Sciences Laboratory Assists in Hanford Cleanup:** A permeable reactive barrier installed in the late 1990s at the Hanford Site has been used to prevent chromate—used to prevent fuel element corrosion in nuclear reactors—from reaching the nearby Columbia

River. However, the toxic material has been detected in several groundwater monitoring wells at the site, indicating premature loss of reductive capacity of the barrier. To inhibit chromate migration, a researcher from the Pacific Northwest National Laboratory has successfully used the subsurface flow and transport capabilities at the Environmental Molecular Sciences Laboratory to conduct column and flow cell experiments to assess the viability of adding zero-valent iron enhanced with polymer solutions to portions of the barrier that have lost reductive capacity. The experiments effectively yielded the necessary polymer, polymer concentration, and injection parameters to considerably improve the effectiveness and longevity of the barrier. Fluor-Hanford is using these results for the design of a pilot test for the insertion of the zero-valent iron and polymer solution to the barrier in FY 2007.

- **Immobilization of Uranium at Oak Ridge Field Research Center:** Results from field-scale studies conducted by investigators from Stanford University and Oak Ridge National Laboratory at the Field Research Center in Oak Ridge, Tennessee, have shown that it is possible to reduce the concentration of mobile uranium from more than 1,000 times the U.S. drinking-water limit to levels at or below the limit. Over the course of a year, the Stanford and ORNL team demonstrated that by injecting ethanol and recirculating the groundwater in a specific part of the contaminant plume they could stimulate the existing microbial community to convert the uranium in the groundwater into an immobile form that precipitated on the soil. These field studies are continuing to examine the range of physical, chemical and biological factors that influence uranium immobilization and determine its long-term stability.
- **Biogeochemistry Grand Challenge Research Determines that a Microbial Outer Membrane Protein Complex Facilitates Electron Transfer to a Mineral Surface:** A team of over twenty university and Pacific Northwest National Laboratory scientists working together as part of PNNL's Biogeochemistry Grand Challenge have shown in laboratory studies that an outer membrane protein complex facilitates the transfer of electrons in the bacteria, *Shewanella oneidensis*, to iron- and manganese-containing mineral phases. Using the experimental and computational capabilities of the EMSL and other team member resources to conduct molecular modeling and experimental research, the investigators have shown that the electron transfer reaction is intrinsically rapid, but is slowed by many orders of magnitude at the mineral-water interface. This process is fundamental to many important environmental reactions, including the immobilization and remediation of some of DOE's most problematic contaminants, including uranium, technetium and chromium.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Environmental Remediation Sciences Research	**52,171**	**50,479**	**52,339**
▪ **Environmental Remediation Sciences Research**	**45,628**	**43,936**	**47,796**

Within this subprogram, the Environmental Remediation Sciences Research activity will address questions of fundamental environmental remediation science at the interfaces of biology, chemistry, geology and physics. The research will help to provide the scientific foundation for the solution of key environmental challenges within DOE's cleanup mission at scales ranging from molecular to the field, including issues of fate and transport of contaminants in the environment; novel strategies for in situ remediation; and long-term monitoring of remediation strategies.

In FY 2008, the research activity will support a tiered set of approximately 100 projects that range from relatively small, specialized, single investigator, laboratory-based research projects to complex, multidisciplinary, large-scale research projects that evaluate processes relevant to the environment at the field scale (approximately $10,000,000). The overall focus and integration strategy will center on field research since the ultimate goal of the Environmental Remediation Sciences subprogram is a conceptual understanding of environmental processes that control contaminant mobility in the subsurface and the development of science-based remediation strategies to influence or control these processes. In addition to research on the environmental processes that control contaminant transport, this activity will develop new tools for measuring and characterizing the broad range of biological, chemical, and geophysical parameters associated with the behavior of contaminants in the environment.

This integrated research effort will lead to the development of improved models to predict the transport of contaminants in the environment and then to validate those predictions using field data. Knowledge of the factors controlling contaminant mobility in the environment is essential to understand the fate of contaminants, before, during, and after remediation, and is a necessary step toward the BER long-term measure for environmental remediation. FY 2008 funding supports research at multiple field research sites, including the existing Oak Ridge, Tennessee site and two additional sites, one at Hanford, Washington and the other at Old Rifle, Colorado (an UMTRA site). All three sites were selected by merit review in late 2006. Additional funding for field research in FY 2008 will expand this activity and enable scientists to evaluate concepts and hypotheses under a greater variety of geohydrologic conditions. The expanded field efforts will have broad applicability to current research programs on heavy metal and radionuclide contamination as well as to the DOE missions of environmental remediation. These enhanced field activities also will emphasize the need for coordination between experimentation and computer simulation as critical components of both experimental design and model development. The expanded field research activities will be used to evaluate and validate the results of laboratory-based science and predictive modeling efforts.

The Environmental Remediation Sciences Research activity within this subprogram will continue to foster interdisciplinary research and be responsive to new knowledge and to advanced computational and analytical tools that emerge from research at the EMSL, the SciDAC program, the synchrotron light sources, and from within the GTL program in support of DOE's clean-up mission.

In FY 2008, BER participation in SciDAC will provide an opportunity for subsurface and computational scientists to develop and improve methods of simulating subsurface reactive transport processes ($972,000). The intent is to explore potential advantages that high-end computing can bring to the understanding of optimal model complexity, the scalability of biogeochemical reactions, model abstraction methods, sources of uncertainty, parameter estimation and characterization measurements as input in subsurface reactive transport modeling.

The research activities are carried out at national laboratories, universities, and private institutions and selected through competitive and merit-reviewed processes.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **General Purpose Equipment (GPE)**	**446**	**403**	**403**

GPE funding will continue to provide general purpose equipment for Pacific Northwest National Laboratory (PNNL) and Oak Ridge Institute for Science and Education (ORISE) such as information system computers and networks, and instrumentation that support multi-purpose research.

▪ **General Plant Projects (GPP)**	**6,097**	**6,140**	**4,140**

GPP funding is continued for minor new construction, other capital alterations and additions, and for buildings and utility systems, such as replacing infrastructure in 30- to 40-year old buildings. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity includes stewardship GPP funding for PNNL and for ORISE. The total estimated cost of each GPP project will not exceed $5,000,000. In FY 2008, funding is reduced as building consolidation efforts over the last two years have reduced the need for funding at both PNNL and ORISE.

Facility Operations	**39,019**	**44,453**	**42,691**
▪ **EMSL Operating Expenses**	**33,537**	**35,649**	**36,228**

The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility located at the Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation. Operating funds are used for: staff support for users; maintenance of instruments and buildings; utilities; environmental safety and health compliance activities; and communications. With over 55 leading-edge instruments and a supercomputer system, the EMSL annually supports approximately 1,600 users. The core EMSL science team networks with the broader academic community as well as with DOE national laboratories and other agencies. EMSL users have access to unique expertise and instrumentation for environmental research, including a Linux-based supercomputer; a 900 MHz nuclear magnetic resonance (NMR) spectrometer that highlights a suite of NMRs in EMSL; a collection 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.

In FY 2008, EMSL operations funding is increased to enhance user facility operations and increase services to users.

▪ **Capital Equipment**	**5,482**	**8,804**	**6,463**

Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility as well as the ability to make upgrades to existing instrumentation and to provide additional capabilities in order to maintain EMSL capabilities for environmental molecular scientific research. In FY 2008, capital equipment funds will be used to enhance capabilities in high-field nuclear magnetic resonance spectroscopy (e.g., cryoprobes), microbial dynamics and visualization capabilities (e.g., coupled systems) and/or data storage, as well as maintain existing user capabilities.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2008, a Field Emission Transmission Electron Microscope (TEM) with a Total Estimated Cost of $4,500,000 will be acquired. This Major Item of Equipment will enable EMSL users to image conversion reactions, including catalytic reactions, under actual reaction conditions at the atomic scale, and to thereby identify the specific reaction sites.

	FY 2006	FY 2007	FY 2008
SBIR/STTR	**—**	**2,264**	**2,400**

In FY 2006, $2,114,000 and $254,000 were transferred to the SBIR and STTR programs, respectively. FY 2007 and FY 2008 amounts are the estimated requirements for continuation of the programs.

	FY 2006	FY 2007	FY 2008
Total, Environmental Remediation	**91,190**	**97,196**	**97,430**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Environmental Remediation Sciences Research	
▪ Within the subprogram, the Environmental Remediation Sciences Research activity is increased to provide enhanced research (e.g., a greater variety of geohydrologic conditions) at the 3 field research sites and to support SciDAC research projects to improve methods of simulating subsurface reactive transport processes on “discovery class” computers.	+3,860
▪ General Plant Projects (GPP) funding is reduced as building consolidation efforts over the last two years have reduced the need for funding.	-2,000
Total, Environmental Remediation Sciences Research	**+1,860**
Facility Operations	
▪ In FY 2008, EMSL operations funding is increased to maintain operations at full capacity.	+579
▪ EMSL capital equipment funding is sufficient to maintain and replace existing user capabilities, and increase capabilities in high-field nuclear magnetic resonance spectroscopy, microbial dynamics and visualization and data storage.	-2,341
Total, Facility Operations	**-1,762**
SBIR/STTR	
▪ SBIR/STTR increases with increases in research funding.	+136
Total Funding Change, Environmental Remediation	**+234**

Medical Applications and Measurement Science

Funding Schedule by Activity

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Medical Applications and Measurement Science			
Medical Applications	138,562	13,608	13,608
SBIR/STTR	—	392	392
Total, Medical Applications and Measurement Science	138,562	14,000	14,000

Description

The mission of the Medical Applications and Measurement Science subprogram is to deliver the scientific knowledge and discoveries that will lead to new radio-isotopically based diagnostic and therapeutic tools, non-invasive medical imaging technology, and bioengineering solutions to medical problems.

Benefits

The basic research supported by the subprogram leads to new diagnostic and therapeutic technologies and reagents for the medical community that impact medical imaging and cancer treatment. The research also leads to the development of new medical devices such as neural prostheses, e.g., an artificial retina.

Supporting Information

The subprogram seeks to develop new imaging technologies and 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. Research capitalizes on the national laboratories' resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The expertise of the national laboratories in micro-fabrication, micro-electronics, material sciences, and computer modeling provides the capability to develop intelligent micro-machines that interface with the brain to overcome disabilities and novel biomedical sensors with a broad range of biomedical applications including neural prostheses, such as the artificial retina.

Coordination with the National Institutes of Health (NIH) is provided through joint participation of NIH research staff and management on BERAC Subcommittees, and NIH technical staff participation on BER merit review panels to reduce the possibility of undesirable duplications in research funding. Members of the Medical Applications and Measurement Science subprogram staff are formal members of the National Cancer Advisory Board, the BioEngineering Consortium (BECON) of NIH Institutes, and are on critical committees of the recently established National Institute of Bioimaging and Bioengineering (NIBIB). BER staff also participate in interagency activities such as the Multi Agency Tissue Engineering Science (MATES) working group that includes representatives of seven agencies and the Office of Science Technology Policy.

The Medical Applications and Measurement Science subprogram continues a substantial involvement of academic scientists along with the scientists at the national laboratories.

Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. A COV review of this subprogram, originally planned for FY 2006, will be delayed until the completion of the ongoing National Academy of Science (NAS) review of U.S. nuclear medicine research and will be combined with the scheduled review of the Life Sciences subprogram in FY 2009.

FY 2006 Accomplishments

Many advances were made in imaging technology in FY 2006. These advances are described below along with applications using those advances that were supported by work-for-others, principally for the National Institutes of Health.

- **RatCAP: A New Instrument for Imaging the Awake Rat:** Conventional animal imaging devices such as the microPET require anesthesia which serves to prevent movement but which also alters brain biochemistry. This limits the translation of results from animals to humans. The RatCAP tomograph for awake rat brain imaging with Positron Emmission Tomography (PET) has been developed. The key electronic components including an Application Specific Integrated Circuit (ASIC), which can be used in a wide variety of applications and full system reconstruction matrix have been completed and successfully tested in living animals.
- **Simultaneous PET/Magnetic Resonance Imaging (MRI) Images:** The combination of PET and MRI into a simultaneous imaging instrument allows the correlation of two complementary functional data sets acquired under identical conditions. The increased anatomic resolution of the MRI greatly enhances the functional PET image. The RatCAP PET scanner has been re-designed from totally non-magnetic materials for retrofitting inside conventional MRI instruments. The PET scanner uses a new, highly integrated Application Specific Integrated Circuit (ASIC) developed at Brookhaven National Laboratory (BNL). Recent studies at BNL demonstrate that this new highly compact, low mass PET scanner works inside an MRI magnet and simultaneous dual images have been obtained.
- **Radiolabeling of Nanoparticles:** A key need for understanding the therapeutic applications and toxicology of nanoparticles and is to develop the radiopharmaceuticals needed to image their biodistribution and movement within living animals. Investigators at BNL have recently labeled cadmium selenium nanoparticles (quantum dots) with carbon-11 and tracked their distribution and metabolism in the living rat using the microPET. This is the first total body imaging of injected nanoparticle distribution and clearance in an experimental animal and provides a methodology for testing the efficacy and safety of nanoparticles.
- **Imaging Studies to Protect the Fetus:** Fetal exposure to the toxic effects of drugs of abuse and therapeutic drugs is a major health issue. However, little is known about the passage of drugs from mother to fetus, or what fetal organs are affected by drugs from the maternal circulation. Investigators at BNL have developed the fetal macaque model combined with PET and MRI as a new scientific tool to assess potential toxic effects of therapeutic drugs used during pregnancy. This is the first imaging technique that can be used to monitor adverse effects of drugs on the fetus.
- **Progress Helping the Blind to See:** The DOE Artificial Retina Program (ORNL; SNL; LANL; ANL; LLNL; BNL; University of Southern California; UC, Santa Cruz; North Carolina State, Cal Tech; and Second Sight Corporation) has completed all pre-clinical testing for the 60 electrode device; it has been approved by the Food & Drug Administration (FDA) for trials in blind patients. The trials will be conducted by NIH. The program has completed design and fabrication of the 256 electrode device and has initiated pre-clinical testing. This multi-electrode device has the potential of restoring a high level of functional vision to patients with retinal blindness.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Medical Applications	**138,562**	**13,608**	**13,608**
▪ **Radiopharmaceuticals and Imaging**	**5,161**	**5,382**	**5,382**

In FY 2008, BER continues to support basic research that builds on unique DOE capabilities in physics, chemistry, engineering, biology, and computational science. It supports fundamental imaging research, maintains core infrastructure for imaging research and development, including imaging of awake animals, and develops new technologies to improve the diagnosis and treatment of psycho-neurological diseases and cancer, and the function of patients with neurological disabilities, such as blindness and paralysis. BER research develops new metabolic labels and imaging detectors for medical diagnosis; tailor-made radiopharmaceutical agents for treatment of inoperable cancers; and the capabilities to more accurately determine the structure and behavior of cells and tissues, information needed to engineer more effective or specific drugs.

Essentially all the research activities are carried out at Brookhaven National Laboratory and are selected through competitive and merit-reviewed processes.

▪ **Artificial Retina**	**8,300**	**8,226**	**8,226**

In FY 2008, BER continues to utilize the resources of the national laboratories in material sciences, engineering, microfabrication and microengineering to develop unique neuroprostheses and continue development of an artificial retina to restore sight to the blind. DOE's goal for the artificial retina project is to develop the technology and fabricate a 1,000+ electrode intraocular device that will allow a blind person to read large print, recognize faces, and move around without difficulty. The DOE-sponsored phase of this effort will be completed in FY 2010.

The research activities are principally carried out at national laboratories and are selected through competitive and merit-reviewed processes.

▪ **Congressionally Directed Activities**	**125,101**	**—**	**—**

Congressional direction was provided in FY 2006 for Univ. of Alabama Dept. of Neurobiology to purchase a FMRI; Baylor University Lake Whitney Assessment; SUNY IT Nano-Bio-Molecular Technical Incubator; San Antonio Cancer Center; University of South Alabama Cancer Research Institute; Indiana Wesleyan University Marion for a registered nursing program; Virginia Commonwealth University Massey Cancer Center; Construction of new science facility at Bethel College; University of Wyoming Coalbed Methane research center; Hampton University Cancer Treatment Center; George Mason University research against Biological Agents; Lehigh University Critical Infrastructure Lab.; St. Thomas University Minority Science center; Seton Hall Science/Tech Center; Alvernia College for a Science and Health Building; Institute for Advanced Learning Research Dansville; Galileo Magnet High School Danville; Washington & Jefferson science initiative; Science building at Waubonsee Community College; AVETeC data mamt.electronics and comm. NextEdge Tech.Park; Duchenne Muscular Dystrophy research Univ. of Washington School of Med.; Duchenne Muscular Dystrophy research Children's National Medical Ctr.; Ohio State University for Earth University; Northeast Regional Cancer Institute; Centenary College laboratory; Construction of Science Center at Midwestern Univ.; Univ. of Oklahoma Center Applications Single-Walled Nanotubes; University of Connecticut live cell molecular imaging;

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

University of Central Florida for optics tech in X-Ray; North Shore-Long Island Jewish Health System Breast Cancer Research; Michigan Research Institute Life Science Research Center; Univ. of Arizona Environmental and Natural Resources Phase II; Children's Hospital of Illinois; Research Equipment Coe College; Loma Linda University Medical Center; Triology Linear Accelerator at Owensboro Medical Health System; Burpee Museum of Natural History; Rockford Health Council; Henry Mayo Hospital to purchase new equipment; Washington State University Radio Chemistry; Lapeer Regional Medical Center linear accelerator; University of Nebraska at Kearney; Science Media program at Ball State University; Franklin and Marshall life science building; Boulder City Hospital; Grady Health system disaster preparedness center project; Great Lakes Science Center; Cleveland Clinic Brain Mapping; Roswell Park Cancer Center; St. Marys Cancer Center Long Beach; National Polymer Center at the University of Akron; Biological and Environmental Center at Mystic Aquarium; Riverview Medical Center oncology program; Saratoga Hospital Radiation Therapy Center; State University of New York- Delhi; Kern Medical Center to purchase and install MRI machine; Western Michigan University Geosciences Initiative; Environmental System Center at Syracuse University; SUNY-ESF Woody Biomass Project; ORNL Supercomputer Connectivity NextEdge Technology Park; Oliveit Nazarene University Science Lab; Northern Virginia Comm. College training biotechnology workers; Recording for the Blind and Dyslexic; Eckerd College Science Center; Notre Dame Ecological Genomics Research Institute; Inland Water Environmental Institute; St. Francis Science Center; Medical Research and Robotics, University of Southern California; Hampshire College National Center for Science Education; Pioneer Valley Life Science Initiative Univ. of Massachusetts; MidAmerica Nazarene Univ. nursing biological science program; Westminster College Science Center; City College of San Francisco-Health Related Equipment; Science South Development; St. Joseph Science Center; University North Carolina Biomedical Imaging; Augsburg College; Morehouse School of Medicine; Jersey City Medical Center; University of Rochester James P. Wilmot Cancer Center; Bronx Community College Center for Sustainable Energy; Texas A&M Lake Granbury and Bosque River Assessment; Methodist College Environmental Simulation Research; Brooklyn College Microscope and Imaging Center; Warner Robins Air Logistics Center; University of Chicago Comer Children's Hospital; Martha's Vineyard Hospital; Joint environmental stewardship at SUNY New Paltz and Ulster CC; Central Arkansas Radiation Therapy Institute/Mountain Home; Children's Hospital of Los Angles; Wake Forest University Institute for Regenerative Medicine; Indianapolis Energy Conversion Institute; Philadelphia Educational Advancement Alliance; Barry University-Miami Shores; Montgomery College Biotechnology Project; Purdue Calument Water Institute; University of Chicago Integrated Bioengineering Institute; Mind Institute in New Mexico; Mississippi State University Bio-fuel Application; University of Louisville Institute for Advanced Materials; Center for River Dynamics and Restoration at Utah State University; Texas Metroplex Comprehensive Imaging Center; Ultra Dense Memory Storage for Supercomputing in Colorado; Health Sciences Research and Education Facility; National Center for Regenerative Medicine; U. of Alabama at Birmingham-Radiation Oncology Functional Imaging Program; University City Science Park, Philadelphia; Jackson State University Bioengineering Complex; Regis University Science Building Renovation Project; St. Jude's Children's Research Hospital; California Hospital Medical Center PET/CT Fusion Imaging System; Mount Sinai Medical Center Imaging and Surgical Equipment; Benedictine University Science Lab & Research Equipment; Swedish American Health Systems; La Rabida Children's Hospital, Chicago; Edward Hospital, Plainfield, IL; Rush Medical Center; Morgan State University

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Center for Environmental Toxicology; Mt. Sinai Hospital Cardiac Catherization Lab; U. of Mass. at Boston Multi-Disciplinary Research Facility & Library; CIBS Solar Cell Development; University Medical Center of S. Nevada Radiology/Oncology Equip.; Pyramid Lake Paiute Tribe Energy Project; University of Delaware Medical Research Facility; St. Francis Hospital, Delaware Linear Accelerator; Wastewater Pollution and Incinerator Plant in Auburn, NY; South Nassau Hospital Green Building; ViaHealth/Rochester General Hospital Emergency Department; University of Vermont Functional MRI Research; Vermont Institute of Natural Sciences; Castleton State College Math and Science Center; Nevada Cancer Institute; Queen's Medical Center Telemedicine Project; Michigan Technological University Fuel Cell Research; St. Francis Hospital Escanaba, Michigan; Sarcoma Alliance for Research through Collaboration; Hackensack University Medical Center Green Building; Hackensack U. Medical Center Ambulatory Adult Cancer Center; College of New Jersey Genomic Analysis Facility; W. Michigan U. Expanded Energy & Natural Resources Learning Ctr; Arnold Palmer Prostate Center; LA Immersive Tech. Enterprise program at the U. of LA-Lafayette; Brown University MRI Scanner; University of Dubuque Environmental Science Center; New School University in New York City; Oregon Nanoscience and Microbiologies Institute; GeoHeat Center at the Oregon Renewable Energy Center; Portland Center Stage Armory Theater Energy Conservation Project; U. of Massachusetts Medical School NMR Spectrophotometer; Mojave Bird Study; Minnesota Center for Renewable Energy; Science Center at Malby Nature Preserve in Minnesota; Existing Business Enhancement Program Building, U. of N. Iowa; Medical University of South Carolina; Community College of Southern Nevada Transportation Academy; South Dakota State University; Univ. of Arkansas Cancer Research Center; Altair Nanotech; UCLA Institute for Molecular Medicine; New York Structural Biology Center; University of North Dakota Center for Biomass Utilization; St. Joseph College, West Hartford alternative sources of energy dem. project; Portland State University's Solar Photovoltaic Test Facility System; Brockton Photovoltaic Initiative.

SBIR/STTR	**—**	**392**	**392**

In FY 2006, $3,560,000 and $427,000 were transferred to the SBIR and STTR programs, respectively. FY 2007 and FY 2008 amounts are the estimated requirements for continuation of the programs.

Total, Medical Applications and Measurement Science	**138,562**	**14,000**	**14,000**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	6,097	6,140	4,140
Capital Equipment	16,878	26,121	23,780
Total, Capital Operating Expenses	22,975	32,261	27,920

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
EMSL Field Emission Transmission Electron Microscope, PNNL	4,500	4,500	—	—	—	4,500	FY 2008

High Energy Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
High Energy Physics			
Proton Accelerator-Based Physics	362,157	376,536	389,672
Electron Accelerator-Based Physics	112,291	117,460	79,763
Non-Accelerator Physics	54,205	59,271	72,430
Theoretical Physics	47,984	52,056	56,909
Advanced Technology R&D	121,601	159,476	183,464
Subtotal, High Energy Physics	698,238	764,799	782,238
Construction	—	10,300	—
Total, High Energy Physics	698,238[a]	775,099	782,238
Stanford Linear Accelerator Center (SLAC) Linac Operations (non-add)[b]	(56,100)	(52,100)	(32,500)
High Energy Physics, excluding SLAC Linac Operations (non-add)[b]	(642,138)	(722,999)	(749,738)

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the High Energy Physics (HEP) program is to understand how our universe works at its most fundamental level. We do this by discovering the most elementary constituents of matter and energy, exploring the basic nature of space and time itself, and probing the interactions between them. These fundamental ideas are at the heart of physics and hence all of the physical sciences. To enable these discoveries, HEP supports theoretical and experimental research in both elementary particle physics and fundamental accelerator science and technology. HEP underpins and advances the DOE missions and objectives through this research, and by the development of key technologies and trained manpower needed to work at the cutting edge of science.

[a] Total is reduced by $7,239,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $16,479,000, which was transferred to the SBIR program; and $1,977,000, which was transferred to the STTR program.

[b] The SLAC linear accelerator (linac) supports operations of the B-factory (funded by HEP) and will also support operations of the Linac Coherent Light Source (currently under construction and funded by Basic Energy Sciences (BES)). With the completion of B-factory operations in FY 2008, SC has been transitioning funding of the SLAC linac from HEP to BES, with FY 2008 representing the third and final year of joint funding with BES. HEP totals without SLAC linac funding are presented to display program growth exclusive of this functional transfer.

Benefits

HEP supports the Department of Energy's (DOE's) mission of world-class scientific research capacity by providing facilities and advancing our knowledge of high energy physics and related fields, including particle astrophysics and cosmology. Research advances in any one of these fields often have a strong impact on research directions in another. These fields also have a substantial overlap in technological infrastructure, including particle accelerators and detectors, data acquisition, and computing. Technology that was developed in response to the demands of high energy physics research has also become critical to other fields of science and has found wide applications in industry and medicine, often in ways that could not have been predicted when the technology was first developed. Examples include: medical imaging, radiation therapy for cancer using particle beams, ion implantation of layers in semiconductors, materials research with electron microscopy, and the World Wide Web. The accelerator technologies of high-power x-ray light sources, from synchrotron radiation facilities to the new coherent light sources, are derived from high energy physics accelerator technology.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The High Energy Physics program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

The HEP program has one GPRA Unit Program Goal which contributes to Strategic Goal 3.1 and Strategic Goal 3.2 in the "goal cascade."

GPRA Unit Program Goal 03.1/2.46.00: Explore the Fundamental Interactions of Energy, Matter, Time and Space - Understand the unification of fundamental particles and forces, and the mysterious forms of unseen energy and matter that dominate the universe; search for possible new dimensions of space; and investigate the nature of time itself.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The HEP program contributes to these Strategic Goals by advancing our understanding of the basic constituents of matter and the forces between them, deeper symmetries in the laws of nature at high energies, and mysterious phenomena that pervade the universe, such as dark energy and dark matter. HEP uses particle accelerators and very sensitive detectors to study fundamental particle interactions at the highest possible energies. Because particle physics is deeply connected to the origin and evolution of the universe itself, the HEP program also supports non-accelerator studies of cosmic particles and phenomena including experiments conducted deep underground, on mountains, or in space. This research at the frontier of science may discover new particles, forces, or undiscovered dimensions of space and time; explain how matter came to have mass; and reveal the underlying nature of the universe. In particular, the HEP program seeks to identify the mysterious dark matter that holds galaxies together and the even more mysterious dark energy that is stretching space apart; explain why there is any matter in the universe at all; and show how the tiniest constituents of the universe play a leading role in shaping its birth, growth, and ultimate fate. Our goals in FY 2008 address all of these challenges.

The FY 2008 budget request also contributes to this program goal by placing high priority on operations, upgrades, and infrastructure for the three major HEP user facilities: the Tevatron Collider and Neutrinos at the Main Injector (NuMI) at the Fermi National Accelerator Laboratory (Fermilab), and the B-factory at the Stanford Linear Accelerator Center (SLAC), to produce maximum scientific data to address these fundamental questions. HEP and Basic Energy Sciences (BES) will jointly support B-factory accelerator operations at SLAC throughout the construction phase of the Linac Coherent Light Source (LCLS). FY 2008 will be the final year of the SLAC linac operations transition to BES.

The following indicators establish specific long-term (10 year) goals in scientific advancement to which the HEP program is committed. They do not necessarily represent the research goals of individual experiments in the field. The order of the indicators corresponds roughly to current research priorities, and is meant to be representative of the program, not comprehensive.

- Measure the properties and interactions of the heaviest known particle (the top quark) in order to understand its particular role in the Standard Model, our current theory of particles and interactions.
- Measure the matter-antimatter asymmetry in many particle decay modes with high precision.
- Discover or rule out the Standard Model Higgs particle, thought to be responsible for generating the mass of elementary particles.
- Determine the pattern of the neutrino masses and the details of their mixing parameters.
- Confirm the existence of new supersymmetric (SUSY) particles or rule out the minimal SUSY Standard Model of new physics.
- Directly discover or rule out new particles that could explain the cosmological "dark matter."

These indicators spell out some of the important scientific goals of the HEP program for the next decade and can only be evaluated over a period of several years. However, each of these long-term goals is supported by one or more of the annual performance targets in Facilities Operations or Construction/Major Items of Equipment listed in the following table. Achieving success in these annual targets will be an important component of making progress towards the long-term goals.

Funding by Strategic and Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 03.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space			
High Energy Physics	698,238	775,099	782,238

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 03.1/2.46.00—Explore the Fundamental Interactions of Energy, Matter, Time and Space					
All HEP Facilities					
Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Goal Not Met]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Goal Not Met]	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time.	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time.
Proton Accelerator-Based Physics/Facilities					
Delivered data as planned (225 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (240 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (390 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (675 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.[Met Goal]	Deliver data as planned within 20% of the baseline estimate (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.	Deliver data as planned within 20% of the baseline estimate (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.
			Delivered data as planned within 20% of the baseline estimate ($1x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.[Met Goal]	Deliver data as planned within 20% of the baseline estimate ($1.5 x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.	Deliver data as planned within 20% of the baseline estimate ($2.0 x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.
Electron Accelerator-Based Physics/Facilities					
Increased the total data delivered to BaBar at the SLAC B-factory by delivering 45 fb^{-1} of total luminosity. [Goal Not Met]	Delivered data as planned within 20% of baseline estimate (45 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]	Delivered data as planned within 20% of baseline estimate (50 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (100 fb^{-1}) to the BaBar detector at the SLAC B-factory.[Met Goal]	Deliver data as planned within 20% of the baseline estimate (150 fb^{-1}) to the BaBar detector at the SLAC B-factory.	Deliver data as planned within 20% of the baseline estimate (220 fb^{-1}) to the BaBar detector at the SLAC B-factory
Construction/Major Items of Equipment					
Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates.[Met Goal]	Maintain cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates.	Maintain cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates.

Means and Strategies

The HEP program will use various means and strategies to achieve its program goals. However, various external factors may impact the ability to achieve these goals.

The HEP program supports fundamental, innovative, peer-reviewed research to create new knowledge in areas important to the HEP mission, i.e., in experimental and theoretical particle physics, particle astrophysics, cosmology, and technology R&D. HEP also plays a critical role in constructing and operating a wide array of scientific user facilities for the Nation's researchers. All research projects undergo regular peer review and merit evaluation based on procedures set down in Office of Science Regulation 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. New projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) changing mission needs as described by the DOE and Office of Science (SC) mission statements and strategic plans; (2) evolving scientific opportunities that sometimes emerge in a way that revolutionizes disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or sub fields, such as those performed by the National Academy of Sciences; (4) unanticipated failures, for example, in critical components of scientific user facilities, which cannot be mitigated in a timely manner; and (5) strategic and programmatic decisions made by other Federal agencies and by international entities.

The HEP program in fundamental science is closely coordinated with the activities of other federal agencies (e.g., the National Science Foundation [NSF] and the National Aeronautics and Space Administration [NASA]). HEP also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of nuclear physics research and facilities; basic energy sciences facilities, (contributing to research in materials science, molecular biology, physical chemistry, and environmental sciences); and mathematical and computational sciences.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to validate and verify performance. Quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department has implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the federal government’s portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The HEP program has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the HEP program a score of 84% overall which corresponds to a rating of “Moderately Effective”. OMB found performance improvements at Fermilab and an ongoing prioritization process. The assessment also found that HEP has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, HEP grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain these complex scientific measures, the Office of

Science has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the High Energy Physics Advisory Panel (HEPAP) and also available on the website, will guide reviews, every three years by HEPAP, of progress toward achieving the long-term performance measures. The annual performance targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB previously provided HEP with three recommendations to further improve performance:

- Implement the recommendations of past and new external assessment panels, as appropriate.
- Develop a strategy and implementation plan for particle accelerator research and development, including a potential international linear collider.
- Engage the National Academies to help develop a realistic long-term plan for the program that is based on prioritized scientific opportunities and input from across the scientific community.

In response to OMB's recommendations HEP has:

- Established a Committee of Visitors (COV) that provides outside expert validation of the program's merit based review processes for impact on quality, relevance, and performance. Within 30 days of receiving a COV report, HEP develops an action plan to respond to its findings and recommendations. The COV reports are available on the web (http://www.science.doe.gov/hep/HEPAPCOVReportfinal.pdf). Action plans are also available on the web at (http://www.sc.doe.gov/hep/OfficeofHEPResponsetoCOVreport.shtm).
- Formally charged the HEPAP to establish panels to assess progress toward the long-term goals of the HEP program.
- Started implementing recommendations from the National Academies study of elementary particle physics ("EPP2010") to develop a prioritized long-term plan.
- Initiated a planning process, with the high energy physics community's input, to develop a strategy for accelerator R&D within DOE that incorporates the challenges of a potential international linear collider.
- Begun actively working to implement recommendations from expert panels as appropriate. HEP plans for future facilities, based upon that input, are reflected in this budget request.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov website. Information concerning HEP PART assessments and current follow up actions can be found by searching on "high energy physics" at http://www.ExpectMore.gov.

Overview

What is the nature of the universe and what is it made of?

What are matter, energy, space, and time?

We have been asking basic questions like these throughout human history. Today, many of these questions are addressed scientifically through research in high energy physics, also known as particle physics. The DOE and its predecessors have supported research into these fundamental questions for more than five decades.

This research has led to a profound understanding of the physical laws that govern matter, energy, space, and time. This understanding is encompassed in a "Standard Model," first established in the 1970's, which predicts the behavior of particles and forces. The model has been subjected to countless experimental tests since then and its predictions have consistently been verified. The Standard Model is one of the great scientific triumphs of the 20th century and the discoveries that led to it have been recognized with more than a dozen Nobel Prizes.

But startling new data have revealed that only about 5% of the universe is made of the normal, visible matter described by the Standard Model. The other 95% of the universe consists of matter and energy whose fundamental nature is a mystery. The Standard Model's orderly and elegant view of the universe must somehow be incorporated into a broader and deeper theory where these new phenomena take their natural places. A revolution in particle physics, and in our understanding of the universe in which we live, is coming.

Questions and the Quest for Answers

A world-wide program of particle physics research is underway to explore the new scientific landscape. The new long-term plan for the U.S. HEP program prepared by the National Academy of Sciences ("Revealing the Hidden Nature of Space and Time") recommends the thoughtful pursuit of a high-risk, high-reward strategy to explore the energy frontier, called the "Terascale". At Terascale (meaning 10^{12} electron volts, or TeV for short) energies, questions in cosmology and particle physics are closely connected: the history, nature, and ultimate fate of the universe depend intimately on elementary particles and their interactions.

Here are some of the key questions the HEP program is addressing, and how we are seeking the answers:

- Are there undiscovered principles of nature: new symmetries, new physical laws?

  The laws of quantum physics that describe elementary particles and forces are based on underlying symmetries of nature. Some of these prevail only at very high particle energies. One new symmetry, called supersymmetry, relates particles and forces. It predicts a "superpartner" for every particle we know, the lightest of which should be produced and observed at accelerators operating at the Terascale.

- How can we solve the mystery of dark energy?

  The "dark energy" that permeates empty space and accelerates the expansion of the universe must have a quantum explanation, in the same way that the quantum theory of light and the atom explained mysterious atomic spectra. More precise experimental data on dark energy, along with new theoretical ideas, are necessary to make progress on this fundamental problem.

- Are there extra dimensions of space?

  "String theory" is an attempt to unify physics by explaining particles and forces as the vibrations of tiny strings. String theory requires supersymmetry and seven extra dimensions of space. Evidence of such extra dimensions which support string theory could be seen at Terascale accelerators.

- Do all the forces become one?

  All the basic forces in the universe could be various manifestations of a single unified force. Unification was Einstein's great, unrealized dream, and recent advances in string theory give hope of achieving it. The discovery of superpartners or extra dimensions at Terascale accelerators would lend strong support to current ideas about unification.

- Why are there so many kinds of particles?

  Three different "families" of quarks and leptons have been discovered. Moreover, quarks and leptons have widely different masses and force couplings. These variations suggest there may be undiscovered simplifying principles that connect quarks and leptons, just as the discovery of quarks simplified the "zoo" of composite particle states discovered in the 1960's. Detailed studies at accelerators will provide the clearest insights into this complex puzzle.

- What is dark matter? How can we make it in the laboratory?

  Most of the matter in the universe is invisible and interacts very rarely with normal matter. This "dark matter" is thought to consist of exotic particles that have survived since the Big Bang. They may be reproduced and studied at Terascale accelerators, or detected in cosmic rays by using ultra-sensitive detectors.

- What are neutrinos telling us?

  Of all the known particles, neutrinos are perhaps the most mysterious. They played an essential role in the evolution of the universe, and flood otherwise empty space, but most pass right through the Earth undeflected and void of interaction. Their tiny masses may imply new physics and provide important clues to the unification of forces. Neutrinos are produced by cosmic rays, where they can be studied, as well as with experiments at accelerators and nuclear reactors.

- How did the universe come to be?

  The Big Bang (our universe) began with a singular disturbance of space-time, followed by a burst of inflationary expansion of space itself. The universe then expanded more slowly and cooled, allowing the formation of stars, galaxies, and ultimately life. Understanding the very early evolution of the universe will require a breakthrough in physics: the theoretical reconciliation of quantum mechanics with gravity.

- What happened to the antimatter?

  By all observation the universe appears to contain very little antimatter, although the Big Bang should have produced equal amounts of matter and antimatter, a fact that is supported by high-energy collisions in the laboratory. Precise accelerator-based measurements of the subtle asymmetries present in the weak nuclear interaction may shed light on how this asymmetry arose.

All these questions are addressed at some level by the existing and planned HEP program described in the rest of this budget request. Theoretical research, technology development, and a wide variety of experimental approaches are working hand-in-hand to provide new opportunities for further discoveries about the fundamental nature of the universe.

How We Work

The HEP program coordinates and funds high energy physics research. In FY 2006, HEP provided about 90% of the federal support for high energy physics research in the nation; the NSF provides most of the remaining support. HEP is responsible for: planning and prioritizing all aspects of its supported research; conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders; supporting 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, DOE 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 DOE and the NSF on a continuing basis regarding the direction and management of the national high energy physics research program. HEPAP regularly meets to advise the agencies on their research programs, assess their scientific productivity, and evaluate the scientific case for new facilities. HEPAP (or a subpanel thereof) also undertakes special studies and planning exercises in response to specific charges from the funding agencies. A HEPAP subpanel called the Particle Physics Project Prioritization Panel (P5) assesses and prioritizes proposals for mid-sized projects that have been endorsed by laboratory program advisory committees or other advisory committees. Priorities recommended by P5 and other subpanels will have an important influence on long-range planning (see Planning and Priority Setting, below). A subpanel called the Neutrino Scientific Assessment Group (NuSAG), reporting jointly to HEPAP and the Nuclear Science Advisory Committee (NSAC), is advising DOE and NSF on specific questions concerning the U.S. neutrino program. A HEPAP subpanel reviewing the DOE advanced accelerator R&D program reported in the summer of 2006, and one on the university HEP research programs of DOE and NSF will report in spring 2007.

The Astronomy and Astrophysics Advisory Committee (AAAC) now reports on a continuing basis to the DOE, as well as to the NSF and NASA, with advice on the direction and management of the national astronomy and astrophysics research programs. The AAAC operates similarly to HEPAP and the two advisory bodies may form joint task forces or subpanels as needed to address research issues at the intersection of high energy physics, astrophysics and astronomy, such as dark energy and dark matter. For example, Task Forces on the cosmic microwave background and dark energy reported in spring 2006, and a Scientific Assessment Group for Dark Matter has recently been formed and is scheduled to report late in spring 2007.

The National Academy of Sciences was chartered by Congress in 1863 to advise the federal government on scientific and technical matters. It fulfills this function principally through the National Research Council (NRC), which conducts decadal surveys of research directions in all fields of physics and astronomy, as commissioned by its Board on Physics and Astronomy. A seminal new study carried out for the DOE and the NSF by the NRC in 2005-2006 assesses and prioritizes opportunities in high energy physics and the tools needed to realize them in the next 15 years. The committee's report, *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics* emphasized the primary importance of the LHC and ILC in the context of a broad and balanced program that also includes among its elements particle astrophysics and neutrino physics. The report is available at http://www7.nationalacademies.org/bpa/EPP2010.html.

Laboratory directors seek advice from their Program Advisory Committees (PACs) to determine the scientific justifications and priorities for the allocation of an important scientific resource—available accelerator beam time. Committee members, most of them external to the laboratory, are appointed by the director. PACs review research proposals requesting beam time and technical resources, judging each proposal's scientific merit and technical feasibility, and recommending whether the proposal should be approved, conditionally approved, deferred, or rejected.

Review and Oversight

The HEP program office 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 research efforts in the national program. Proposals to DOE for grant support are peer-reviewed by 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. Proposals by university groups to perform an experiment at a laboratory facility are reviewed by the laboratory PAC as described above.

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 programmatic health of the laboratory, its high energy physics research, 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. Proposals to initiate significant new research activities at laboratories may also undergo a peer review process, in addition to the annual laboratory reviews, to assess in detail the quality and relevance of the specific proposal. In addition, the HEP program office began in FY 2004 to conduct regular, dedicated reviews of operations at its major user facilities in order to maintain high standards of performance and reliability. The HEP program office also participates in the annual SC reviews of each of its laboratories.

Review and oversight of construction activities are done by integrated technical, cost, schedule, and management reviews using teams of experts versed in the areas of activity pertinent to the particular project. These reviews are chaired by SC federal employees from outside the HEP program who are expert in project management, and the review results are provided directly to the project's DOE Acquisition Executive.

As noted above in the PART section, the HEP program has also instituted a formal Committee of Visitors that will provide an independent review of its responses to proposals and its research management process, as well as an evaluation of the quality, performance and relevance of the research portfolio and an assessment of its breadth and balance. The first such review took place in the second quarter of 2004, and a second review is planned for 2007. The committee report praised the program strongly, but also pointed to several areas that could be improved.

Planning and Priority Setting

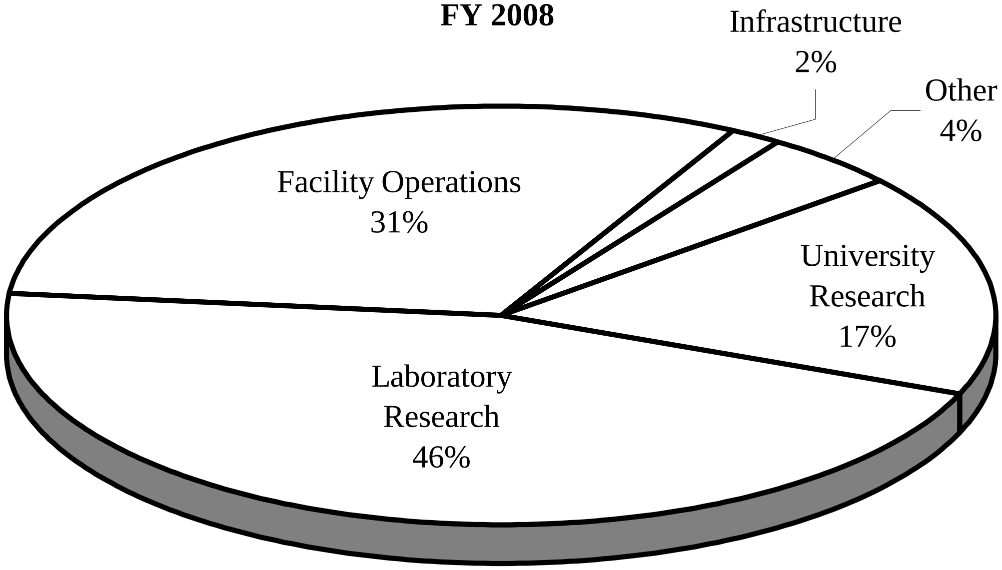
One of the most important functions of HEPAP is the development of long-range plans that express community-wide priorities for future research. The original plan for U.S. high-energy physics in 2010 and beyond was developed by HEPAP in 2002 and presented a "roadmap" for the field, laying out the physics opportunities envisioned for the next 20 years. This plan has since been reviewed and updated by the 2006 National Academies study of particle physics (see Advisory and Consultative Activities, above) which delineated the broad priorities for the future of the field, beginning with the physics enabled by the LHC and the ILC.

HEPAP has recommended a mechanism to update the roadmap and set research priorities across the program. This recommendation has been implemented in the form of the P5 subpanel that is charged with advising the funding agencies on priorities for new facilities. P5 is now playing an important role in determining which new facilities appear on the HEP roadmap in future years. Several scientific review panels (including P5) are currently meeting to evaluate specific proposed future HEP facilities and recommend a detailed programmatic roadmap.

How We Spend Our Budget

The HEP budget has three major program elements: research, facility operations, and laboratory infrastructure support. About 31% of the FY 2008 budget request is primarily provided to the three major HEP facilities for facility operations (Tevatron Collider and NuMI at Fermilab and B-factory at SLAC); a total of 46% is provided to laboratories, including multipurpose laboratories, in support of their HEP research and advanced technology R&D activities; 17% is provided for university-based physics research and advanced technology R&D; 2% for infrastructure improvements (general plant projects [GPP] and general purpose equipment [GPE]); and 4% for other activities (including Small Business Innovative Research [SBIR] and Small Business Technology Transfer [STTR]). It is notable that DOE provides about 70% of the Federal core support for university-based research groups working in high energy physics, including most of the support for students and postdoctoral researchers. The FY 2008 budget request is focused on facility operations and research at Fermilab with the CDF and D-Zero detectors at the Tevatron, and the Main Injector Neutrino Oscillation Search (MINOS) detector using the NuMI beam; and facility operations and research at SLAC with the BaBar detector at the B-factory. Priority is also given to the ramp-up of the LHC research program to support operations and maintenance activities in anticipation of the initial startup of the LHC in the fall of 2007; and to a significant increase in R&D efforts focused on research in superconducting RF technology and development needed for future accelerator facilities including an International Linear Collider.

High Energy Physics Budget Allocation
FY 2008



Research

The DOE HEP program supports approximately 2,400 researchers and students at more than 100 U.S. universities located in 36 states, Washington, D.C., and Puerto Rico, and 10 DOE national laboratories located in 6 states. In addition, the HEP research program includes significant participation from university scientists supported by the NSF, a substantial number of scientists from foreign institutions, and scientists supported by NASA. These physicists conceive and carry out the high energy physics research program. Typically, they work together in large international collaborations, involving hundreds of scientists from many institutions, to carry out a program that may take a decade or more to complete. A long time scale is one of the signature features of high energy physics research. Funding for most university and laboratory research is maintained at approximately the FY 2007 level-of-effort, with the main emphasis on supporting analysis of the large datasets now being generated by our user facilities, and enhancing long-range accelerator science research. Research scientists at national laboratories and universities work together in the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories also maintain state-of-the-art resources needed for future upgrades and new facilities, and together with the university-based research program, perform R&D for future detectors and accelerator facilities.

- **University Research:** University researchers play a critical role in the national high energy physics research effort and in the training of graduate students and postdoctoral researchers, only about half of whom remain in the field, the rest going into industry, commerce and government where they are well-received. This highly trained human resource is part of the Nation's economic and strategic strength. During FY 2006, the DOE High Energy Physics program supported approximately two-thirds of the nation's university researchers engaged in fundamental high energy physics research, and approximately 90% of the researchers engaged in accelerator R&D. Typically, about 100 Ph.D.

degrees are granted annually to students for research supported by the high energy physics program and 10 per year in the accelerator physics 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 grants are competitively awarded according to the guidelines published in Office of Science Regulation 10 CFR 605. Thereafter, the research is monitored to ensure that a high quality of research is maintained (see Review and Oversight, above).

- **National Laboratory Research**: The HEP program supports research groups at the Fermi National Accelerator Laboratory; at Lawrence Berkeley, Lawrence Livermore, Argonne, Brookhaven, Oak Ridge, and Los Alamos National Laboratories; and at the Princeton Plasma Physics Laboratory, SLAC and the Thomas Jefferson National Accelerator Facility. 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 play a key role in developing and maintaining the accelerators, large experimental detectors, and computing facilities for data analysis. Laboratory researchers play a critical role in the national high energy physics research effort and in the training of postdoctoral researchers, engineers and technical personnel, many of whom spend much of their later careers in industry.

  The HEP program funds selected 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 and balance 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.

Significant Program Shifts

The U.S. HEP program in FY 2008 will continue to lead the world with forefront user facilities at Fermilab and SLAC that help answer the key scientific questions outlined above, but these facilities are scheduled to complete their scientific missions by the end of the decade. The mid-term HEP program supported by this request continues to develop new cutting-edge facilities in targeted areas (for example, neutrino physics) that will establish a U.S. leadership role in these areas in the next decade, when the centerpiece of the world HEP program will be the LHC at the European Organization for Nuclear Research (CERN). For the long-term, we have prioritized our current R&D efforts to select those that will provide the most compelling science opportunities in the coming decade within the available resources.

For these reasons, our highest priority R&D effort is the development of the proposed International Linear Collider (ILC) followed by efforts to expand the program in particle astrophysics and pursue an internationally coordinated, staged program in neutrino physics. In making these decisions we have carefully considered the recommendations of the National Academy of Sciences, HEPAP, and planning studies produced by the U.S. HEP community. This prioritization process will continue as the R&D programs evolve.

- The planned operational improvements, equipment, upgrades and infrastructure enhancements for the Tevatron program at Fermi National Accelerator Laboratory will be completed by FY 2007. The luminosity improvements of the Tevatron Collider have been successfully carried out while still running the collider at high efficiency. As part of its ongoing development of a U.S. HEP program “roadmap” for the upcoming decade, the HEP prioritization subpanel (P5) will consider the scientific importance of outyear (FY 2009 and beyond) Tevatron running in spring 2007.

- Much of the accelerator improvement effort at Fermilab will move to the neutrino program, which began in 2005 with the commissioning of the NuMI neutrino beam. The NuMI beam uses the proton source section of the Tevatron complex, and puts high performance demands on that set of accelerators. A new program of enhanced maintenance, operational improvements, and equipment upgrades has been developed to meet these demands. An initial set of accelerator improvements will be completed in 2008 to upgrade the NuMI beam power from its design value of about 250 kW to about 400 kW. Additional improvements are being developed that would further enhance the NuMI beam power and provide a platform for a world-leading neutrino program at Fermilab into the next decade. Since these improvements will most directly benefit the NuMI Off-axis Neutrino Appearance (NOνA) detector[a], the upgrade of the NuMI beam power from 400 kW to 700 kW will be incorporated into the NOνA project using standard DOE project management protocols.
- In order to exploit the unique opportunity to expand the boundaries of our understanding of the fundamental and asymmetry between matter and antimatter in the universe, a high priority is given to completing the physics program of the B-factory at SLAC. Final upgrades to the accelerator and detector are scheduled for completion in FY 2007, and B-factory operations will conclude in FY 2008. As part of its ongoing development of a U.S. HEP program "roadmap" for the upcoming decade, the HEP prioritization subpanel (P5) evaluated the scientific importance of the final year (2008) of B-factory running, and has recommended that B-factory operations continue through 2008. The transition of SLAC from primarily supporting B-factory operations to construction and operations of the Linac Coherent Light Source in Basic Energy Sciences is discussed in the Facilities Summary, below.
- As the LHC accelerator nears its turn-on date in 2007, U.S. activities related to fabrication of detector components will be completed and new activities related to commissioning and pre-operations of these detectors, along with software and computing activities needed to analyze the data, will ramp-up significantly. Support of an effective role for U.S. research groups in LHC discoveries will continue to be a high priority of the HEP program. R&D for possible future upgrades to the LHC accelerator and detectors will also be pursued.
- R&D for the ILC is maintained at the FY 2007 request level to support U.S. participation in a comprehensive, coordinated international R&D program, and to provide a basis for U.S. industry to compete successfully for major subsystem contracts should the ILC be built. The long-term goal of this effort is to provide robust cost and schedule baselines to support design and construction decisions for an international electron-positron linear collider near the beginning of the next decade. The ILC Reference Design Report will be completed in early 2007, and further work toward the design, including some site-specific studies and detector studies, will be performed during FY 2007. In FY 2008, further work toward a final design of both accelerator systems and detector studies will be performed.
- Accelerator technology R&D will be increasingly focused on superconducting radiofrequency (RF) structures in view of their potentially wide applicability to many scientific and other applications. A broad spectrum of SC programs need a domestic industrial capability, not presently available, to produce cost competitive and reliable superconducting RF components for possible future electron and proton accelerators that serve the science mission. The FY 2008 request supports further research and development of superconducting RF technology in the United States.

[a] This project was originally proposed as a line-item construction project in the FY 2007 Congressional Budget under its original generic name of EνA for Electron Neutrino Appearance.

- A coordinated neutrino program developed from an American Physical Society study and a joint HEPAP/NSAC subpanel review is well underway, and includes the NOνA Detector, a large new detector optimized to detect electron neutrinos, and a new reactor-based neutrino experiment in China. In FY 2008 fabrication will begin on two small new neutrino experiments: Main Injector Experiment ν-A (MINERνA) in the MINOS near detector hall at Fermilab, which will measure the rates of neutrino interactions with ordinary matter, and Tokai-to-Kamioka (T2K) in the near detector hall of the Japanese J-PARC neutrino beam in Tokai. R&D will continue for a possible large double beta decay experiment to measure the mass of the neutrino.
- Support for R&D on ground- and space-based dark energy experimental concepts, begun in FY 2007, will be continued in FY 2008. These experiments will provide important new information about the nature of dark energy, leading to a better understanding of the birth, evolution, and ultimate fate of the universe. For example, SNAP will be a mission concept proposed for a potential interagency-sponsored experiment with NASA, and possibly international partners, the Joint Dark Energy Mission (JDEM). DOE and NASA are jointly funding a National Academy of Sciences study to determine which of the proposed NASA "Beyond Einstein" missions should launch first, with technical design of the selected proposal to begin at the end of this decade; JDEM is one of the candidate missions in this study.
- In spring 2006, the Dark Energy Task Force, a subpanel of both HEPAP and the AAAC, recommended a mix of experiments with independent and complementary measurements to address the nature of dark energy. Later in the year, the P5 prioritization subpanel of HEPAP recommended that DOE and NSF jointly pursue the Dark Energy Survey (DES) project, a small-scale ground-based experiment that can provide significant advances in our knowledge of dark energy in the near term. In FY 2008, fabrication will begin for DES subject to successful agency review. P5 also recommended that R&D be done for large-scale ground-based and space-based dark energy experiments to get them to a preliminary design stage.
- The apparent changes in many subprogram areas reflect a change in the way that certain program overhead-type expenses (e.g., management, computing and networking, and engineering support) are charged at Fermilab. As an almost entirely HEP-only laboratory (99% HEP and 1% other SC programs), Fermilab has not previously assessed these expenses across program elements, instead directly assessing Facility Operations for the full cost of these activities. With the planned completion of Tevatron collider operations on the horizon, reconsideration of this approach was warranted. Beginning in FY 2007 (after enactment of an appropriation), Fermilab will assess these expenses through a proportional allocation across all Fermilab activities, resulting in redistribution of funds among HEP categories. The FY 2008 funding request reflects the expected redistribution: while Research and Technology R&D activities at Fermilab reflect an increase as a result of this change, there are corresponding decreases reflected in Facility Operations at Fermilab, so there is no net programmatic impact. Since HEP funds about 99% of Fermilab's activities, impacts outside of HEP are negligible.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC mission areas with the goal of achieving scientific breakthroughs via advanced computer science and simulations that are unattainable using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit Terascale computing and networking resources. The program is bringing computation and simulation into parity with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate modeling and prediction, plasma physics, particle physics, accelerator design, astrophysics, chemically reacting flows, and computational nanoscience.

More details on the specific scientific impact of HEP contributions to SciDAC programs on lattice gauge Quantum Chromodynamics (QCD) calculations, grid technology and deployment, accelerator simulation and modeling, and astrophysical simulations, as well as the FY 2008 work plan, can be found below in the description of the Theoretical Physics subprogram.

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 three major high energy physics facilities: the Tevatron Collider at Fermilab, the NuMI neutrino beam line at Fermilab, and the B-factory at SLAC. The Tevatron Collider provided a total of 4,531 hours of beam time in FY 2006 for a research community of about 700 U.S. scientists in HEP and another 700 researchers from foreign countries, testifying to the fact that this is a unique, world-leading experimental facility. Operation of NuMI began in FY 2006 and served more than 250 researchers, of whom about two-thirds are U.S. researchers. Approximately 500 researchers world-wide participate in Fermilab's other experimental and theoretical research and R&D programs. The FY 2008 request will support facility operations at Fermilab that will provide about 5,040 hours of beams for the Tevatron Collider and for NuMI, including an allowance for increased power costs and incremental upgrades. The B-factory provided a total of about 5,130 hours of beam time in FY 2006 for a research community of about 300 U.S. scientists in HEP and a comparable number of users from foreign countries. SLAC also hosts approximately 500 researchers world-wide who are active in its other experimental and theoretical research and R&D programs. The FY 2008 request will support facility operations at SLAC that provide about 5,720 hours of beams for the B-factory. For additional details on SLAC linac operations funding, see the Facilities Summary below.

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.

	FY 2006	FY 2007	FY 2008
Tevatron Complex at Fermilab			
Optimal hours (estimated)	4,320	4,560	5,400
Scheduled Beam Hours - Tevatron	4,531	4,560	5,040
Unscheduled Downtime - Tevatron	23%	<20%	<20%
Scheduled Beam Hours - NuMI	4,531	4,560	5,040
Unscheduled Downtime - NuMI	23%	<20%	<20%
Total Number of Users	2,125	2,160	2,160

	FY 2006	FY 2007	FY 2008
B-factory at SLAC			
Optimal hours (estimated)	5,200	5,200	5,850
Scheduled Beam hours	5,130	5,200	5,720
Unscheduled Downtime	18%	<20%	<20%
Total Number of Users	1,100	1,100	1,100

Construction and Infrastructure

A new Major Item of Equipment (MIE), the NuMI Off-axis Neutrino Appearance (NOνA) Detector is planned to begin fabrication in FY 2007. The NOνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget (under its original generic name of EνA for Electron Neutrino Appearance). It has been re-configured as a MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be provided by a financial assistance vehicle to a third party, funded through operating funds in the Proton Accelerator-Based Physics subprogram, described in the Detailed Justification section that follows. The project also includes improvements to the proton source to increase the intensity of the NuMI beam.

New MIEs included in this request to begin fabrication in FY 2008, subject to successful agency reviews, are the Dark Energy Survey project; the Reactor Neutrino Detector[a]; MINERνA, a small experiment to measure neutrino interaction rates in the MINOS near hall; and U.S. contributions to the T2K neutrino oscillation experiment. A new AIP project will begin in FY 2008 to relocate an experimental test region for accelerator science research from its original site at the end of the SLAC Linac to the South Arc area of the unused SLAC Linear Collider, which completed operations in 1998. Funding for GPP is provided to improve site-wide infrastructure at Fermilab, SLAC, and Lawrence Berkeley National Laboratory (LBNL).

Workforce Development

The HEP program supports development of the R&D workforce through support of graduate students working toward a doctoral degree and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program does more than provide new scientific talent in areas of particle physics research, it provides unparalleled talent for a wide variety of technical, medical, and industrial areas that require the incisive thinking and problem solving abilities and the computing and technical skills that are developed through education and experience in a fundamental research field. Scientists trained as high energy physicists can be found working in industry, academia, and government, in such diverse areas as hospitals (radiation therapy, medical imaging, and medical physics), national security, space exploration, software and computing, telecommunications, finance, and many other fields.

About 1,125 postdoctoral associates and graduate students supported by the HEP program in FY 2006 were involved in a large variety of theoretical and experimental research, including advanced technology R&D. About one-fifth are active in theoretical research. Of those involved in experimental research, about 85% utilize a number of scientific accelerator facilities supported by the DOE, NSF, and foreign countries; and about 15% participate in non-accelerator research.

---

[a] The Department plans to submit a request when the FY 2007 appropriation is enacted to reprogram $3,000,000 of MIE funds towards ongoing R&D.

Details of the High Energy Physics program workforce are given below. These numbers include people employed by universities and laboratories. The university grants include both Physics Research and Accelerator Technology grants. In FY 2006, there were about 135 university grants with average funding of $750,000 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.

	FY 2006 actual	FY 2007 estimate	FY 2008 estimate
# University Grants	135	140	140
# Laboratory Groups	47	47	47
# Permanent Ph.D.'s (FTEs)	1,210	1,250	1,250
# Postdoctoral Associates (FTEs)	540	595	600
# Graduate Students (FTEs)	585	620	635
# Ph.D.'s awarded	115	110	110

In addition, there is a joint DOE/HEP and NSF research-based physics education program ("QuarkNet") aimed at professional development for high school teachers. In this program, active researchers in high energy physics serve as mentors for high school teachers to provide long-term professional development based on participation in frontier high energy physics research. Through these activities, the teachers enhance their knowledge and understanding of science and technology research. They transfer this experience to their classrooms, engaging their students in both the substance and processes of contemporary research as appropriate for the high school classroom. For more details see the Detailed Justification section that follows.

Facilities Summary

Fermilab

In FY 2008, Fermilab plans 5,040 hours of running for both the Tevatron Collider program and the Tevatron neutrino physics program. The annual goal for the Tevatron Collider program is to achieve a performance goal of 800 inverse picobarns (pb^{-1}) of data delivered to the major Tevatron Collider experiments. Approximately 900 people are involved in day-to-day Tevatron Collider operations that include operation of the Tevatron accelerator complex and the CDF and D-Zero detectors for the collider program. This is one of the major data collection periods for the Collider experiments studying fundamental properties of matter and their interactions and also searching for supersymmetry, extra dimensions, and possible observation of the long-awaited Higgs boson at the world's energy frontier facility. Tevatron Collider operations are currently scheduled to end after FY 2009, when the Large Hadron Collider should be running at its design luminosity.

Tevatron operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron Collider operations. This mode is used for physics data taking by the MINOS experiment and for test beam runs (both using 120 GeV protons extracted from the Main Injector). During FY 2008, the MINOS experiment will be operating its beam line and detectors to collect data. Test beam runs will be scheduled as needed. These functions do not interfere with the high-priority Tevatron Collider operations.

Fully achieving the physics goals of the Tevatron program over the next few years has required a series of significant performance improvements to the accelerator complex. These efforts are proceeding in parallel with current Tevatron operations and research program. The technical scope, cost and schedule of work for the accelerator upgrades is periodically reviewed by the SC Office of Project Assessment and the reports from their reviews are available on the HEP website at http://www.science.doe.gov/hep/TevatronReports.shtm. The most recent review of the Tevatron operations was conducted in March 2006.

Fermilab facilities operations funding is summarized in the table below:

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Tevatron Complex Operations	169,390	191,500	158,000
Tevatron Complex Improvements	40,135	24,255	58,220
Total, Tevatron Complex	209,525	215,755	216,220

SLAC

In FY 2008, SLAC plans 5,720 hours of running to achieve a performance goal of 220 inverse femtobarns (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 HEP research program at SLAC, in its final year of operation in FY 2008. The collected data will provide: a significant enhancement to the BaBar dataset for precision studies of Charge-Parity (CP) violation in the B-meson system, a phenomenon related to the excess of matter over antimatter in the universe; measurements of the defining parameters of the Standard Model of particle physics; and high precision searches for possible small violations of the predictions of the Standard Model in rare decays of heavy quark systems. These efforts are more fully described in the Detailed Justification sections that follow.

For decades, SLAC has been one of the world’s leading research laboratories in 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. With the advent of the Linac Coherent Light Source (LCLS) project, the role that SLAC plays in x-ray science has greatly expanded. Indeed, after the planned shutdown of the B-factory at the end of FY 2008, the SLAC linac will be dedicated to the world’s first x-ray free electron laser. The potential applications of this new experimental tool are legion: nanotechnology, solid-state physics, biology, energy production, medicine, electronics, and fields that do not yet exist. Recognizing the importance of the SLAC linac to the BES program, the Office of Science has been transitioning support for the SLAC linac from HEP to BES, with FY 2008 marking the third and final year of split funding.

HEP funding for SLAC linac operations is contained within the B-factory Operations and B-factory Improvements lines within the Electron Accelerator-Based Physics/Facilities activity. The following tables identify the SLAC linac funding amounts within HEP and overall.

SLAC Linac Operations Funding within HEP

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Electron Accelerator-Based Physics/Facilities			
B-factory Operations			
Linac Operations	42,800	44,100	21,900
Other B-factory Operations	29,824	38,792	20,964
Total, B-factory Operations	72,624	82,892	42,864
B-factory Improvements			
Linac Improvements	13,300	8,000	10,600
Other B-factory Improvements	3,800	2,000	2,338
Total, B-factory Improvements	17,100	10,000	12,938
Total, Electron Accelerator-Based Physics/Facilities	89,724	92,892	55,802
(Total, HEP SLAC Linac Operations and Improvements)	(56,100)	(52,100)	(32,500)
(Other Electron Accelerator-Based Physics/Facilities)	(33,624)	(40,792)	(23,302)

Total SLAC Linac Operations Funding

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Basic Energy Sciences SLAC Linac Operations	29,400	40,000	61,500
High Energy Physics SLAC Linac Operations and Improvements	56,100	52,100	32,500
Total, SLAC Linac Operations	85,500	92,100	94,000

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007 the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Proton Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Proton Accelerator-Based Physics			
Research	80,939	79,738	94,658
Facilities	281,218	296,798	295,014
Total, Proton Accelerator-Based Physics	362,157	376,536	389,672

Description

The mission of the Proton Accelerator-Based Physics subprogram is to foster fundamental research in high energy physics using proton accelerators that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Proton Accelerator-Based Physics subprogram exploits U.S. leadership at the energy frontier by conducting experimental research at high energy proton collider facilities. This experimental research program will determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and will search for the first clear evidence of new physics beyond the Standard Model.

The Proton Accelerator-Based Physics subprogram also includes precise, controlled measurements of basic neutrino properties performed at accelerator facilities, since neutrino beams are generated from primary proton beams. These measurements will provide important clues and constraints to the new world of matter and energy beyond the Standard Model. This subprogram addresses five of the six long-term indicators that contribute to the Program Goal as well as the majority of the key questions outlined in the HEP Overview section above.

Supporting Information

The most immediate goal on the particle physics roadmap is to fully understand the unification of the electromagnetic and weak nuclear interactions into a single, “electroweak” force. This is expected to occur at an energy scale of about one trillion electron volts or 1 TeV. The Standard Model has successfully explained almost all particle physics phenomena below 1 TeV in energy, but beyond that energy range a new physical mechanism must be present to prevent Standard Model predictions from becoming unphysical. Originally it was proposed that a single Higgs boson is the solution to this “TeV scale” problem, but newer theories such as supersymmetry, extra hidden dimensions, and technicolor could also solve the TeV scale problem in the Standard Model, either in place of or in combination with, one or more Higgs bosons. No matter which of these theories is shown to be correct, it will provide a deeper understanding of the fundamental nature of matter, energy, space, and time. One thing is clear, however: new physics must occur at the Terascale.

Because of the high energy of the collisions at the Tevatron Collider (2 TeV) and the LHC (14 TeV), and the fact that the particles interact in different ways, these facilities can be used to study a wide variety of physics topics. All of the six known types of quarks can be produced in these interactions, but the heaviest, the top and bottom quarks, are of the greatest interest. Most of the force-carrying particles are also produced in these collisions, and if the masses of predicted—but as yet unobserved—particles, such as the Higgs boson or supersymmetric particles are small enough, they will also be discovered. Whether the Tevatron or the LHC is the first accelerator to observe new physics at the TeV scale will depend on the configuration nature has chosen for these phenomena.

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 also be produced and formed into beams for experiments. The Proton Accelerator-Based Physics subprogram uses both aspects of proton accelerators.

The major activities under the Proton Accelerator-Based Physics subprogram are broad research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab; the neutrino research program using the NuMI/MINOS facility at Fermilab and at the Soudan Mine site in Minnesota; the LHC program; and maintenance and operation of these facilities.

Physics at the energy frontier is the primary thrust of the Proton Accelerator-Based Physics subprogram. In FY 2008, the energy frontier moves to the LHC in Europe. The LHC program will substantially increase the ability of U.S. high energy physicists to explore physics beyond the Standard Model and will enable the U.S. to remain involved as a key player at the energy frontier. But while the LHC experiments will be just beginning to acquire experience with their first physics-quality data, the well-understood CDF and D-Zero experiments will continue to perform forefront searches for new physics at the TeV scale, such as the Higgs, and making precision measurements of known particles—like the mass of the W boson and the top quark—that will indicate where the Higgs or other new physics is likely to be found. The number of top quarks accumulated and studied during the previous Tevatron collider run from 1992 to 1996 was less than 100. The new run (started in 2001) has already produced an order of magnitude more top quarks, and will provide far more precise measurements of its mass, spin, and couplings.

Today, neutrino physics presents one of the most promising avenues to probe for extensions of the Standard Model. In the last decade, a number of interesting new results have been reported by several different experiments, including the Super-K and KamLAND experiments in Japan and the Sudbury Neutrino Observatory (SNO) experiment in Canada. These experiments provide compelling evidence that neutrinos do have mass and do change their identities (the different neutrino species “mix”) as they travel. These properties of neutrinos are neither required nor predicted by the Standard Model. Unfortunately, the neutrinos used by these experiments have a wide range of energies and are produced in insufficient numbers to precisely measure their mixing parameters. One of the unique opportunities in the Proton Accelerator-Based Physics subprogram is to explore and make high precision measurements of neutrinos generated at dedicated proton beam facilities in a well-controlled environment (e.g., the NuMI beam at Fermilab). The NuMI/MINOS program is making decisive controlled measurements of fundamental neutrino properties, including neutrino mixing, and will provide important clues and constraints to the theory of matter and energy beyond the Standard Model.

The National Academy of Sciences “EPP2010” report recommended a diverse HEP program using a variety of tools to attack the exciting opportunities in elementary particle physics, including a staged internationally coordinated program in neutrino physics. One of those opportunities, the observation of electron neutrinos from a muon neutrino beam, can be met by the proton accelerator-based research program. A new detector optimized to detect electron neutrinos, NuMI Off-axis Neutrino Appearance (NOνA) Detector, is planned to begin fabrication in FY 2007 and will utilize the NuMI beam.

Research and Facilities

The Research activity in the Proton Accelerator-Based Physics subprogram supports university-based and laboratory-based scientists performing experimental research at proton accelerator facilities in the

U.S. and abroad. Experimental research in this area is a collaborative effort undertaken by research groups from Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Fermilab, LBNL, SLAC, and about 60 colleges and universities. The research activities 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, and at universities where many of the scientists are located. The university program also provides a small amount of funds at national laboratories (University Service Accounts) to allow university groups to travel and perform specific tasks connected with the experimental research program, such as purchasing needed supplies from laboratory stores.

The Facilities activity in the Proton Accelerator-Based Physics subprogram supports maintenance, operation, and technical improvements for proton accelerator facilities in the U.S. In addition, this category supports the U.S. share of detector maintenance and 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; provision of computing hardware and software infrastructure to support the experiments and the accelerators, and provision of 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 institutions.

Highlights

Recent accomplishments include:

- The CDF and D-Zero detectors at Fermilab have collected over 20 times more data in Run II of the Tevatron collider than that of all of Run I (1992-1996). CDF has reported the world's first observation of the very rapid particle-antiparticle oscillations of the heavy B mesons that contain a strange quark (called "B_s mesons"). D-Zero has a slightly less sensitive measurement that is in agreement with the CDF result. The results are based on 1.0 fb^{-1} of integrated luminosity, about two-thirds of the collected data. This result supplies additional information independent of the precision measurements of B-meson mixing done at the B-factory. The measured rate of B_s-meson oscillations is consistent with the Standard Model range of predictions.
- The MINOS collaboration has announced their first observation of the oscillation of muon neutrinos using the NuMI beamline. This result validates the performance of the MINOS detector and the NuMI beam, based on the neutrinos produced by 1×10^{20} protons colliding with the neutrino production target. The measurement is the most precise in the world, and is consistent with previous measurements, reaffirming the current picture of neutrino masses and oscillations. The experiment is planned to run through FY 2010 to achieve its ultimate sensitivity, about a factor of two improvement over its current result.

The major planned efforts in FY 2008 are:

- *The research program using the Tevatron at Fermilab*. This research program is being carried out by a collaboration including 1,400 scientists from Fermilab, ANL, BNL, LBNL, 56 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2008 will be data taking with the fully upgraded CDF and D-Zero detectors. The physics issues to be addressed include searches for the Higgs boson, supersymmetry, or other new phenomena; B meson studies including charge-parity (CP) violation; and precision measurements of the top quark and the W boson properties. The involvement of researchers will decrease somewhat as the LHC effort commences.

- *The research program using the NuMI/MINOS Facilities at Fermilab and the Soudan Mine*. This research program is being carried out by a collaboration including 250 scientists from Fermilab, ANL, BNL, Lawrence Livermore National Laboratory (LLNL), 16 U.S. universities, and institutions in 4 foreign countries. The major effort in FY 2008 will be data taking and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics. A new experiment, Main Injector Experiment ν-A (MINERνA), which will make precision measurements of neutrino interaction rates in the NuMI beam (an important input to analyze MINOS and NoνA data), begins fabrication in FY 2008.
- *A new detector for neutrino physics.* Fabrication is planned to begin in FY 2007[a] for a new Major Item of Equipment, the NuMI Off-axis Neutrino Appearance (NOνA) Detector. The NOνA detector will use the NuMI beam from Fermilab to directly observe and measure the transformation of muon neutrinos into electron neutrinos over distances of hundreds of miles. The project also includes improvements to the proton source to increase the intensity of the NuMI beam. The occurrence of these particular neutrino "flavor" changes is expected to be much rarer than the phenomenon that MINOS is studying. Funding for NOνA will ramp-up in FY 2008.
- *Planning and preparation for the U.S. portion of the research program of the LHC*. A major effort in FY 2008 will be the implementation and optimization of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Commissioning and maintenance of U.S.-supplied detectors for LHC experiments at CERN will continue as a top priority.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**80,939**	**79,738**	**94,658**
▪ **University Research**	**47,541**	**47,694**	**50,865**

The HEP university research 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 opportunities and preliminary designs for future experiments; and train graduate students and postdoctoral researchers. University-based scientists 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

[a] The EνA detector was originally proposed as a line-item construction project ($10,300,000) in the FY 2007 Congressional Budget but has been renamed NOνA and has been reconfigured as a MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

laboratory groups. University personnel are fully integrated into the operations of the detector facilities, performing various service functions, and these facilities could not operate without them. University-based research efforts are funded in a manner based on peer review, and at an overall level commensurate with the effort needed to carry out the experiments. Proton accelerator activities concentrate mainly on experiments at the Tevatron Collider at Fermilab; development of the physics program for the LHC; and the MINOS, NOνA, and MINERνA neutrino experiments at Fermilab and the Soudan Mine.

In FY 2008, the overall level of support is at about the FY 2007 level-of-effort to maintain strong participation in the Tevatron, LHC, and neutrino physics programs. Within the total, there will be some continued redirection of effort to LHC activities in FY 2008. Strong participation of university physicists is needed to exploit the physics potential of the very active collider and neutrino program at the Tevatron during FY 2008, and there will be healthy scientific competition between completion of the Run II of the Tevatron Collider program and commencement of the LHC experiments. The detailed funding allocations will take into account the quality of research as well as the involvement of university-based research groups in the targeted physics research activities. These include research efforts related to the Tevatron experiments CDF and D-Zero; the NuMI neutrino experiments MINOS, NOνA, and MINERνA; and U.S. participation in the LHC research program. U.S. university researchers are also contributing to a new accelerator-based neutrino oscillation experiment (T2K) in Japan. A new MIE project to build a detector for the T2K beam line begins fabrication ($2,000,000) in FY 2008 (estimated TEC $3,000,000).

▪ **National Laboratory Research**	**32,219**	**30,548**	**42,312**

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 embedded in the laboratory structure and therefore 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. Proton accelerator activities concentrate on experiments at the Tevatron complex (collider and neutrino physics programs) at Fermilab and the LHC at CERN.

In FY 2008, the national laboratory research program is increased above the FY 2007 level of effort to maintain strong participation in the Tevatron, LHC, and neutrino physics programs. However, approximately 45% of the increase is due to an accounting change at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding categories, as described in the Significant Program Shifts section above. The activities supported by these costs include computing support, general engineering and technical support, program management, and business office expenses.

The remaining increase in laboratory research supports enhanced participation of laboratory physicists in the ATLAS and CMS experiments as LHC operations and data analysis begin. Full participation of national laboratory physicists is also needed to exploit the physics potential of the research program at the Tevatron during FY 2008, and there will be healthy scientific

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

competition between the completion of the Run II of the Tevatron Collider program and commissioning of the LHC experiments. HEP will monitor progress in these areas, and balance resources as needed to optimize the national program.

The Fermilab research program includes data taking and analysis of the CDF, D-Zero, and MINOS experiments; the CMS research and computing program; and research related to the new neutrino initiatives, such as the NOνA and MINERνA experiments. This research by physicists at the host laboratory provides the necessary close linkages between the Research and the Facilities activities in the Proton Accelerator-Based Physics subprogram.

Research at LBNL will be dominated by the ATLAS research and computing program, along with analyzing data from the CDF experiment.

The BNL research group will focus on the ATLAS research and computing program, data taking and analysis of the D-Zero experiment, and a small effort on the MINOS experiment and research related to future neutrino initiatives.

The research group at ANL will be working on data taking and analysis of the CDF experiment, the ATLAS research and computing program, data taking and analysis of the MINOS detector, and research related to the new neutrino initiatives, such as the NOνA experiment.

A small research group from SLAC joined the ATLAS experiment in 2006 and will be engaged in LHC research and data analysis.

▪ **University Service Accounts**	**1,179**	**1,496**	**1,481**

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. Funding for these university service accounts is maintained at about the FY 2007 level, reflecting the overall size of the University Research program, and work at the new LHC Physics Center at Fermilab.

Facilities	**281,218**	**296,798**	**295,014**
▪ **Tevatron Complex Operations**	**169,390**	**191,500**	**158,000**

Operations at Fermilab will include operation of the Tevatron accelerator complex for both collider and neutrino physics programs, including two collider detectors and a neutrino experiment. This will be a major physics run for the D-Zero and CDF detectors with the higher intensity available from the upgraded Main Injector. The Tevatron performance has continued to improve according to plan through FY 2006 and this is to be one of the major data collection periods for the collider experiments pursuing physics topics from the energy frontier facility.

Tevatron operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron collider operations. This running mode will be primarily for the physics data taking of the MINOS experiment using the NuMI beamline.

In FY 2008, the decrease in this category is due largely to accounting changes at Fermilab that move costs for direct program support from Operations to Research and Technology R&D funding categories, as described in the Significant Program Shifts section above. The activities

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

supported by these costs include computing support, general engineering and technical support, program management, and business office expenses. About 85% of the decrease is due to these changes. The remainder is due to actual reductions in operations and commissioning activities as the NuMI proton improvement plan to increase the intensity of the proton source from 250 kW to about 400 kW is completed. Funding for these upgrades decreases from $6,258,000 in FY 2007 to $1,050,000 in FY 2008, the final year of funding. Additional funding for these upgrades is included in Tevatron Complex Improvements below.

	FY 2006	FY 2007	FY 2008
Tevatron Complex Operations in hours	4,531	4,560	5,040

	FY 2006	FY 2007	FY 2008
▪ **Tevatron Complex Improvements**	**40,135**	**24,255**	**58,220**

The funding in this category includes funds for GPP projects and other infrastructure improvements at Fermilab, funding for accelerator improvements, experimental computing expansion and other detector support, and new detector fabrication. Accelerator improvements to increase the luminosity performance of the Tevatron Collider were completed in FY 2006, and the laboratory began to focus effort on improving the intensity of the NuMI beamline beyond its design power of 250 kW via a phased plan of incremental upgrades referred to as the NuMI proton improvement plan. The plan involves upgrading beam controls and collimation so that the Tevatron complex can accommodate higher proton intensities and NuMI can provide more neutrinos to the MINOS experiment. In FY 2008, the third and final year of the proton improvement plan funding ($500,000) will support deployment and commissioning of these improvements to increase the intensity of the proton source to about 400 kW. FY 2007 funding was $5,578,000 and additional funding for the proton improvement plan is included under Tevatron Complex Operations above.

After the completion of Tevatron Collider Run II, it will be possible to adapt portions of the existing collider complex to support operations of the NuMI beam-line at even higher intensity than is possible during Run II. The Recycler, which currently serves as a storage ring for antiprotons, can be reconfigured to accept protons and provide a higher net proton throughput than is possible with the current accelerator configuration. This reconfiguration can raise the beam power to the NuMI target from 400 kW to 700 kW. Improvements to the cooling, shielding and power supplies in the Booster, Main Injector, and NuMI beam-line would also be done to support the higher beam intensity.

The increase in neutrino intensity that can be achieved with this reconfiguration will be very important to support the physics goals of the NuMI Off-axis Neutrino Appearance (NOνA) Detector, so this collection of upgrades and improvements has been added to the scope of the NOνA project (see below) in order to ensure appropriate project management oversight and integration. Since these accelerator improvements were part of the outyear facilities planning for Fermilab, this change has no net budgetary impact. FY 2008 funding for this activity ($10,000,000) primarily supports procurement of needed materials.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

The fabrication of the NOνA Detector is planned to begin in FY 2007 and ramps up significantly in FY 2008. The upgrades to improve NuMI beam intensity to 700 kW (described above) have been added to the scope of the NOνA MIE project and have increased its estimated TPC by approximately $60,000,000. The TPC and TEC for NOνA will not exceed $260,000,000 and $155,200,000, respectively. The NOνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget under its original generic name of EνA for Electron Neutrino Appearance[a]. Funding for this project is included in this category starting in FY 2008. This detector is optimized to identify electron-type neutrinos, and using the NuMI beam from Fermilab it will observe for the first time the transformation of muon-type into electron-type neutrinos.

NOνA will also make important indirect measurements from which we may be able to determine the mass hierarchy for the three known neutrino types (i.e., whether there are two “light” and one “heavier” type of neutrino or vice versa), which will be a key piece of information in determining the currently unknown masses of neutrinos. The project includes the very large “far” detector itself (approximately football-field size and five stories high), the far detector enclosure, its associated electronics and data acquisition system, and a small “near” detector on the Fermilab site. FY 2008 funding for the NOνA detector ($21,150,000) supports the first year of a cooperative agreement to build an enclosure for the detector and participate in the NOνA research program, along with final design and initial fabrication of detector elements ($4,900,000).

	FY 2006	FY 2007	FY 2008
NOνA (TEC)	—	—[a]	4,900
NOνA (OPC)			
Proton Improvements (400 kW to 700 kW)	—	—	10,000
Other Projects Costs (R&D and cooperative agreement)	4,300	—[a]	21,150
Total, NOνA (OPC)	4,300	—	31,150
Total, NOνA (TPC)	4,300	—[a]	36,050

[a] $10,300,000 was originally requested in FY 2007 as a line item construction project for EνA. The project has since been reconfigured as the NOνA MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer the EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

Also included in this category is $5,000,000 to begin fabrication of a new MIE called MINERνA (estimated TEC $10,000,000). This is a small experiment in the MINOS near detector hall at Fermilab that will measure the rates of neutrino interactions with ordinary matter. This is useful input data for MINOS and other neutrino experiments including NOνA, and can be measured with much better precision than previous experiments using the powerful NuMI beam.

	FY 2006	FY 2007	FY 2008
▪ **Large Hadron Collider Project**	**7,440**	**3,180**	**—**

Under the agreement with CERN regarding U.S. participation in the LHC program, DOE has provided $450,000,000 to the LHC accelerator and detectors (with an additional contribution of $81,000,000 from the NSF). The DOE total provided was separated into detectors ($250,000,000) and accelerator ($200,000,000), with the accelerator funding consisting of $88,500,000 for direct purchases by CERN from U.S. vendors, and $111,500,000 for fabrication of components by U.S. laboratories.

In addition to the $450,000,000 DOE and $81,000,000 NSF contributions to the fabrication of LHC accelerator and detector hardware, U.S. participation in the LHC involves a significant fraction of its physics community in the research program at the LHC. This involvement, supported by the core research funds of the DOE and the NSF has grown dramatically, with over 900 U.S. scientists anticipated as members of the U.S.-ATLAS detector collaboration, the U.S.-CMS detector collaboration or the U.S.-LHC accelerator consortium by FY 2008. Most of the effort in FY 2008 will be devoted to the U.S. LHC Research Program, which will deploy the infrastructure needed for exploiting the rich physics opportunities presented by the new energy frontier to be opened as the LHC ramps up to full energy in 2008, see LHC Support below.

The overall U.S. LHC Project reached a status of 97% complete by the end of FY 2005, in compliance with the “CD-4a” project-completion requirement prescribed by the DOE. Essentially all of the equipment is already at CERN, and the remaining portion of the accelerator project was completed in 2006. The two detector projects, tied to the final stages of the CERN schedule, will be completed before the end of FY 2008. The latter activities are related primarily to the final assembly, testing, and installation of the completed detectors, as well as to the purchase of computing hardware for data acquisition. Under the current schedule, completion of these two detector projects will take place in calendar year 2007, in full agreement with the U.S. DOE deadline for the completion of the project. The overall result of previous delays in the CERN schedule was a stretch-out by two years in the planned U.S. contributions to the LHC detectors. The final cost of each detector remains unchanged, and the final year of DOE funding for all aspects of the U.S. participation in fabrication of the LHC is FY 2007.

U.S. LHC Accelerator and Detectors Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation (Detectors)
	Accelerator	Detectors	Total	
1996[a]	2,000	4,000	6,000	—
1997[a]	6,670	8,330	15,000	—
1998[a]	14,000	21,000	35,000	—
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	21,310	37,900	59,210	9,720
2004	29,330	19,470	48,800	—
2005	21,447	11,053	32,500	—
2006	—	7,440	7,440	—
2007	—	3,180	3,180	—
Total	200,000[b]	250,000	450,000	81,000

LHC Detectors Funding Summary

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
LHC Detectors			
ATLAS Detector			
Operating Expenses	1,642	1,034	—
Capital Equipment	1,598	846	—
Total, ATLAS Detector	3,240	1,880	—
CMS Detector			
Operating Expenses	1,300	50	—
Capital Equipment	2,900	1,250	—
Total, CMS Detector	4,200	1,300	—
Total, LHC Detectors	7,440	3,180	—

[a] 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

[b] Includes $111,500,000 for LHC supporting R&D and accelerator components to be fabricated by U.S. laboratories and $88,500,000 for purchases by CERN from U.S. vendors.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **Large Hadron Collider Support**	**52,641**	**56,820**	**62,000**

With final preparations for LHC turn-on in late 2007, the U.S. LHC program, jointly supported by the DOE and the NSF, will enter a critical phase in FY 2008. An increase of 9% in DOE support above FY 2007 is planned. The main use of the resources will be for LHC software and computing, and pre-operations and maintenance of the U.S.-built systems that are part of the LHC detectors. The U.S. also participates in accelerator commissioning and accelerator physics studies using the LHC, along with R&D for potential upgrades to both the machine and the detectors. These efforts are described in more detail below. The U.S. LHC effort is one of the highest priority components of the HEP program, endorsed repeatedly by HEPAP, and by the recent National Academy of Sciences study. With quality data expected before the end of FY 2008, it is imperative to focus attention on the needs anticipated during the ramp-up of operations in FY 2008.

• **LHC Software and Computing**	**19,984**	**22,596**	**24,369**

The LHC software and computing effort will enable U.S. physicists to analyze the vast quantities of LHC data in a transparent manner, and empower them to play a leading role in exploiting the physics opportunities presented by the LHC. The LHC Software and Computing program will also enter a critical stage in FY 2008, when the combination of software development, facilities hardware and support, and grid computing must come together. Prior to FY 2008, the U.S. effort will be focused on data and service challenges, with testing of the hardware and infrastructure needed for full LHC data analysis using professional-quality software on simulated data. These systems have to grow rapidly from prototypes to fully functional systems in 2007. The funding ramp-up in FY 2008 will provide equipment purchases, computing personnel, and user support at Tier 1 and Tier 2 computing and data handling centers in the U.S. This will allow U.S. physicists, especially at universities, to maintain the central role during data analysis that they played during fabrication of detectors. Grid computing solutions will continue to be integrated in the LHC computing model, building on the tools provided by the SciDAC Open Science Grid project, and providing U.S. researchers the access and computing power needed to analyze the large and complex LHC data. In FY 2008, full-scale analysis with physics-quality data will form the final testing ground for the completed systems.

• **LHC Experimental Support**	**21,657**	**23,224**	**25,631**

Funding for operations and maintenance of the LHC detector subsystems built by U.S. physicists will increase somewhat in FY 2008 as the first year of LHC data will fully test the capabilities of these detectors. This effort will support the continuing development and deployment of tools for control, calibration, and exploitation of LHC data, including remote detector monitoring and control systems. These tools will facilitate remote participation by U.S. physicists in the pre-startup activities at the LHC, ensuring proper commissioning and operation of U.S.-supplied components. U.S. LHC collaborators will perform integration tests of the major detector subsystems using final data-acquisition systems and fully commission their detector

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		

subsystems. The effort on detector R&D, with specific focus on detector technologies needed to accommodate a possible LHC upgrade in luminosity, will start to increase. Support will also be provided for technical coordination and program management, both at the participating U.S. national laboratories and at CERN.

• **LHC Accelerator Research**	**11,000**	**11,000**	**12,000**

The U.S. LHC Accelerator Research Program (LARP), supported solely by the DOE, will continue to focus R&D on producing full-scale accelerator-quality magnets with the highest possible sustained magnetic fields. This R&D also provides important technical data to CERN for management decisions on possible future LHC accelerator upgrades to increase luminosity. This effort ramped-up significantly in FY 2006. In FY 2008, funding is increased by 9%, as fabrication begins on advanced prototypes of state-of-the-art LHC interaction region magnets made of optimized niobium-tin (Nb_3Sn) superconductor material. Special instrumentation is also being provided for collimation and monitoring of the LHC beams that will play an important role during the accelerator commissioning phase.

▪ **Alternating Gradient Synchrotron (AGS) Support**	**650**	**650**	**650**

Operations at BNL for HEP experiments using the AGS facility were terminated at the end of FY 2002. Funding continues for close-out costs and long-term decontamination and decommissioning (D&D).

▪ **Other Facilities**	**10,962**	**20,393**	**16,144**

Includes funding for private institutions and other government laboratories and institutions that participate in high energy physics research, as well as recurring contributions to general program operations activities, such as the federal laboratory consortium, financial auditing, support for internal and external program and project reviews, personnel support under the Intergovernmental Personnel Act, and technical consultation on programmatic issues. This category also includes funding to respond to new opportunities and unexpected changes in facilities operations and support.

Includes $1,154,000 for General Purpose Equipment and $4,535,000 for General Plant Projects at LBNL for landlord related activities. Also includes $2,300,000 for LHCNet, the transatlantic data link between the U.S. and CERN.

Total, Proton Accelerator-Based Physics	**362,157**	**376,536**	**389,672**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ University Research is increased to maintain strong participation in the Tevatron, LHC and neutrino physics programs. Full participation of HEP researchers is needed to exploit the physics potential of the very active program at the Tevatron during FY 2008, in parallel with initial operations of the LHC experiments ($1,171,000). Also includes the first year of funding to begin fabrication of the T2K Near Detector MIE ($+2,000,000).	+3,171
▪ National Laboratory Research is increased to maintain strong participation in the Tevatron, LHC and neutrino physics programs. About 45% of the increase is due to accounting changes at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding categories; the remainder is redirection of research effort to the LHC program and new neutrino experiments.	+11,764
▪ University Service Accounts at Fermilab decrease as some research effort moves to the LHC program.	-15
Total, Research	**+14,920**
Facilities	
▪ Funding for Tevatron Complex Operations is decreased due to accounting changes at Fermilab where the direct support costs for the entire laboratory had been 100% assigned under Facilities Operations and are now being distributed to Research and Technology R&D activities. The net effect is that funding for Tevatron Operations decreases and funding for all Fermilab Research and Technology R&D activities increases. About 85% of the decrease in this category is due to these changes; the remainder ($-5,208,000) is due to reductions in operations and commissioning activities as the improvements to raise the NuMI proton intensity from 250 kW to about 400 kW are completed.	-33,500
▪ Funding for Tevatron Complex Support increases due to the reclassification of the NOνA experiment as a Major Item of Equipment (from EνA, a line item construction project in the FY 2007 request), and the ramp-up of that project, including accelerator improvements to further increase NuMI proton intensity to about 700 kW ($+36,050,000); as well as the beginning of fabrication for the MINERνA experiment ($+5,000,000). These increases are somewhat offset as the support for the NuMI proton improvements to 400 kW is completed ($-5,078,000) and general support activities ($-2,007,000) are slightly reduced.	+33,965
▪ In the LHC Project, U.S. contributions to the ATLAS and CMS detectors are completed in FY 2007 as scheduled.	-3,180

	FY 2008 vs. FY 2007 ($000)
▪ In the LHC Support effort, U.S. contributions to LHC software and computing, maintenance and operations of the ATLAS and CMS detectors, and LHC accelerator research increase in FY 2008 as the LHC turns on for its first year of physics data.	+5,180
▪ In Other Facilities, resources held pending completion of peer and/or programmatic review decrease.	-4,249
Total, Facilities	**-1,784**
Total Funding Change, Proton Accelerator-Based Physics	**+13,136**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Electron Accelerator-Based Physics			
Research	22,567	24,568	23,961
Facilities	89,724	92,892	55,802
Total, Electron Accelerator-Based Physics	112,291	117,460	79,763

Description

The mission of the Electron Accelerator-Based Physics subprogram is to foster fundamental research in high energy physics using electron accelerators that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Electron Accelerator-Based Physics subprogram utilizes accelerators with high-energy and ultra-precise beams to create and investigate matter at its most basic level. It was the electron accelerator at SLAC that, in the 1960's, first identified the existence of quarks as the inner constituents of the proton and neutron. During the 1980's, electron accelerators—in tandem with proton machines—were instrumental in establishing the Standard Model as the precise theory of particle interactions.

Over the last few years, the electron B-factory at SLAC has provided precision measurements of how matter and antimatter behave differently in the decay products of B-mesons. This asymmetric behavior is called "CP [charge-parity] violation" and is considered by physicists to be vital to understanding why the universe appears to be predominantly matter, rather than equal quantities of matter and antimatter, one of the greatest puzzles we face in comprehending the universe. This subprogram addresses two of the six long-term indicators that contribute to the Program Goal and several of the key questions identified in the HEP Overview section above.

Supporting Information

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.

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). After the observations of CP violation in B mesons were made early in this decade at the SLAC B-factory and a similar accelerator at the Japanese national laboratory for high energy physics, the High Energy Accelerator Research Organization (KEK) B-factory, it has been 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 ongoing study requires both new measurements of CP violation in other B meson decays, as well as measurements of other properties of particles containing bottom or charm quarks. The measurements of these other properties have been used as inputs to the theoretical calculations of CP violation, as our current knowledge of those properties limits our understanding of CP violation.

In addition to studies of CP violation, the BaBar experiment at the SLAC B-factory has pursued a broad program of research on particles containing bottom or charm quarks. The Belle experiment at the KEK B-factory has carried out a similar program, with a small number of U.S. university researchers participating. There has been regular cooperation as well as competition between the BaBar and Belle experiments, leading to more precise measurements and a better understanding of the experimental results. The CLEO-c experiment at the Cornell Electron Storage Ring (CESR) has been concentrating on certain measurements of particles containing charm quarks that are difficult to do at the B-factory. These results test theories used to interpret the CP violation measurements and to provide key inputs to the physics analyses done at the B-factory. The CLEO-c research program will be extended at the recently upgraded Beijing Electron Positron Collider to improve precision measurements of charm quarks and tau leptons.

Research and Facilities

The Research activity in the Electron Accelerator-Based Physics 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, along with a large number of foreign research institutions, and include analysis and interpretation of data and publication of results. The university program also includes a small amount of funds at national laboratories (University Service Accounts) to allow university groups to perform specific tasks connected with the experimental research program.

The Facilities activity in the Electron Accelerator-Based Physics subprogram supports the maintenance and operations of, and technical improvements to, electron accelerator facilities in the U.S., including: 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, 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 U.S. universities and foreign institutions.

Highlights

Recent accomplishments include:

- In FY 2006, the SLAC B-factory delivered 100 fb^{-1} (inverse femtobarns) of which the BaBar detector recorded 98 fb^{-1}. The BaBar collaboration promptly analyzed and presented the latest results, with 74 papers submitted for publication in peer-reviewed journals in 2006, a record for the collaboration. At the major biennial summer research conference in 2006, the BaBar collaboration contributed 114 papers and 26 talks on a full spectrum of new results.
- BaBar has made substantial progress on a comprehensive set of measurements for CP-violating asymmetries, a systematic exploration of rare decay processes, and detailed studies to elucidate the dynamics of processes involving heavy quarks. Combined data from BaBar and Belle have continued to explore hints of possible new physics beyond the Standard Model which were present in the early data in a class of B meson decays to particles (such as K mesons) which contain the strange quark. Though most of these hints of new physics have not increased in significance in the interim, neither have they gone away. These detectors will double their current datasets by 2008, which will provide ample opportunities for discovery.

The major planned efforts in FY 2008 are:

- *The research program at the B-factory/BaBar Facility at SLAC*. This research program is being carried out by a collaboration of approximately 600 physicists including scientists from LBNL, LLNL, SLAC, 40 U.S. universities, and institutions from 7 foreign countries. In FY 2008 this effort will focus on final data taking with the upgraded accelerator and detector. The physics issues to be addressed include expanding our understanding of CP violation in many particle decay modes.
- *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 CESR and the KEK-B electron accelerator facilities. A total of 4 U.S. university groups work at KEK-B, and 22 U.S. university groups work at CESR. CESR, operated by the NSF, will also complete running in FY 2008.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**22,567**	**24,568**	**23,961**
▪ **University Research**	**14,036**	**15,539**	**15,539**

The HEP university research program includes groups at about 40 universities doing experiments at electron accelerator facilities. These university groups analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and postdoctoral researchers. The current Electron Accelerator-Based Physics subprogram is focused on the study of charm and bottom quarks and the tau leptons, all of which are 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 has been pursuing a broad program of physics studies on particles containing bottom or charm quarks with CP violation measurements and other measurements that support or complement the CP violation program.

U.S. university scientists constitute about 50% of the personnel needed to analyze the BaBar experiment at the B-factory, and they work in collaboration with groups from national laboratories and foreign institutions. They are fully integrated into the operations of the detector facility, and perform many service functions for the detector.

The university program also supports groups that work at CESR at Cornell University; and groups that work at the KEK-B accelerator complex in Japan. The CLEO-c experiment at CESR is concentrating on certain precise measurements of particles containing charmed quarks that are difficult to perform at the B-factory. There is regular cooperation, as well as competition between the SLAC and KEK experiments, which has led to better data analysis and more precise results. University-based research efforts will be selected based on peer review.

In FY 2008, funding for the university program is maintained at the FY 2007 level, in order to support analysis of the unprecedented amount of physics data generated by the B-factory, and physics simulations for other electron accelerators. The detailed funding allocations will take into account the involvement of university based research groups in targeted physics research activities. These include research efforts related to high priority efforts in BaBar research.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**8,293**	**8,698**	**8,094**

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. The experimental research groups from national laboratories provide invaluable service in the operation of the detector as well as analysis of the data. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. The experimental research group from SLAC participates in all phases of the experiments. Because they are embedded in the laboratory structure, they provide invaluable service in the upgrade, calibration, and operation of the detector as well as reconstruction and analysis of the data. The experimental research group at LBNL makes significant contributions to the physics analysis of the data and the computing system needed to reconstruct the data into physics quantities used for analysis. The LLNL research group contributed to the fabrication of the BaBar detector and is now primarily engaged in data analysis.

In FY 2008, the electron-based national laboratory research program is decreased somewhat as some research effort at SLAC moves to the LHC program. Overall SLAC will continue to maintain strong participation in the B-factory research program, and efficiently maintain B-factory operations.

▪ **University Service Accounts**	**238**	**331**	**328**

University Service Accounts facilitate the support of university groups working at accelerator facilities, providing funding for these groups to purchase needed supplies 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.

Facilities	**89,724**	**92,892**	**55,802**
▪ **B-factory Operations**	**72,624**	**82,892**	**42,864**
• **Linac Operations**	**42,800**	**44,100**	**21,900**
• **Other B-factory Operations**	**29,824**	**38,792**	**20,964**

Funding for operations supports the final scheduled year of running of the B-factory accelerator complex and the operation of the BaBar detector. Total operations time scheduled for data collection in FY 2008 is 5,720 hours. In addition to the $21,900,000 requested within this activity for SLAC Linac operations, $10,600,000 is requested in B-factory Improvements below, and $61,500,000 is requested in support of the Linac Coherent Light Source (LCLS) project by the Basic Energy Sciences (BES) program (see the Facilities section of the BES Materials Science and Engineering subprogram). The BES contribution to linac operations is increased by $21,500,000 over FY 2007, while total HEP funding for SLAC linac operations decreases by $19,600,000.

Direct program support costs at SLAC will be charged to Research and Technology R&D funding categories in FY 2008, instead of under Operations, similar to the accounting changes at Fermilab described under Tevatron Complex Operations above. The activities supported by these costs include computing support, general engineering and technical support, program management and business office expenses. The change relative to FY 2007 is a reduction of about $7,500,000 in this funding category.

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

BaBar will be the priority HEP research program at SLAC in FY 2008. It is anticipated that the collected data will ensure a U.S. leadership role in the study of CP violation, allowing researchers to determine whether remaining discrepancies in physics results between the SLAC B-factory and the KEK-B are signs of new physics, and to search for other discoveries that may be revealed.

	FY 2006	FY 2007	FY 2008
B-factory Operations in hours	5,130	5,200	5,720

	FY 2006	FY 2007	FY 2008
▪ **B-factory Improvements**	**17,100**	**10,000**	**12,938**
• **Linac Improvements**	**13,300**	**8,000**	**10,600**
• **Other B-factory Improvements**	**3,800**	**2,000**	**2,338**

Funding is provided for the necessary enhancement of computing capabilities in order to support the timely analysis of the flood of data the B-factory has provided over the past few years. Activities in this category also include support for GPP funding to renew site-wide infrastructure, as well as general accelerator support and maintenance activities.

Overall funding is increased over FY 2007, mainly to support a new accelerator improvement (AIP) project ($2,500,000) to relocate an experimental test region for accelerator science research to the South Arc area of the unused SLAC Linear Collider, which completed operations in 1998. The existing test facility had occupied a site at the end of the SLAC Linac, where part of the new Linac Coherent Light Source (LCLS) is now being constructed. Beam from the SLAC Linac can be switched to the South Arc when LCLS is not operating. The relocated experimental capability is called the South Arc Beam Experimental Region, or SABER. SABER will provide a unique experimental capability that will enable a wide variety of research projects in advanced beam and plasma physics.

In the first phase of SABER, it will operate parasitically with LCLS, using Linac pulses that are not needed for LCLS operations. Potential upgraded configurations under consideration for the future would provide positrons to SABER and allow for independent LCLS and SABER operations. The total cost for SABER (including potential future upgrades, should they be approved, as well as its initial configuration) is estimated to be approximately $17,000,000, though it may be possible to re-use some B-factory accelerator components to reduce the overall cost.

	FY 2006	FY 2007	FY 2008
Total, Electron Accelerator-Based Physics	**112,291**	**117,460**	**79,763**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
National Laboratory Research and University Service Accounts at SLAC decrease as some research effort at SLAC moves to the LHC program.	-607
Facilities	
▪ HEP funding for B-factory Operations decreases significantly as increased support is provided for SLAC Linac operations by the Basic Energy Sciences (BES) program, and direct program support costs move from Operations to Research and Technology R&D funding categories.	-40,028
▪ Funding for B-factory Improvements is increased over FY 2007 to support the first phase of SABER ($+2,500,000), an AIP project to relocate an accelerator science research capability to the South Arc area of the unused SLAC Linear Collider, for continued use as an experimental test region, along with a modest increase ($+438,000) to maintain the FY 2007 level-of-effort in B-factory support activities in the final year of accelerator operations.	+2,938
Total, Facilities	**-37,090**
Total Funding Change, Electron Accelerator-Based Physics	**-37,697**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Non-Accelerator Physics			
University Research	17,977	17,271	18,205
National Laboratory Research	27,536	25,957	35,662
Projects	8,349	15,554	17,941
Other	343	489	622
Total, Non-Accelerator Physics	54,205	59,271	72,430

Description

The mission of the Non-Accelerator Physics subprogram is to foster fundamental research in elementary particle physics using naturally occurring particles and phenomena that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those topics in particle physics that cannot be investigated completely with accelerators, or are best studied by other means. These activities—including the search for or measurement of dark matter and dark energy—have provided experimental data, new ideas, and techniques complementary to those provided by accelerator-based research. These research activities align with the program mission on investigations of elementary particles and their interactions. This subprogram addresses two of the six long-term indicators that contribute to the Program Goal and several of the key questions identified in the HEP Overview section above.

Supporting Information

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 and phenomena. University and laboratory scientists in this subprogram investigate topics such as dark matter, dark energy, neutrino properties, proton decay, the highest energy cosmic rays, and primordial antimatter. In addition, high energy gamma ray observations yield information about active galactic nuclei, gamma ray bursters, massive black holes, and particle acceleration mechanisms that are far beyond the capabilities of any accelerators on earth. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of significant new physics.

Some of the non-accelerator-based particle sources used in this research are neutrinos from the sun, galactic supernovae, terrestrial nuclear reactors, and cosmic rays in the earth's atmosphere. These experiments utilize particle physics techniques and scientific expertise, as well as the infrastructure of our national laboratories; and are often located at remote sites, such as in deep underground laboratories, on mountain tops, across deserts, or in space, either as dedicated satellites or as instruments attached to NASA facilities such as the International Space Station.

Research and Facilities

The Non-Accelerator Physics subprogram supports the university and laboratory scientists performing experimental particle physics, astrophysics, and cosmology 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 universities. This program is carried out in collaboration with physicists from DOE national laboratories and other government agencies and institutes including NSF, NASA, the Naval Research Laboratory (NRL), and the Smithsonian Astrophysical Observatory. Strong interagency coordination and collaboration is one of the hallmarks of the efforts in this subprogram. As in 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 experimental measurements. While research activities (including remote site operations of Non-Accelerator Physics experiments) are covered under the Research activities, the Projects activity in the Non-Accelerator Physics subprogram supports the technical R&D, engineering and design, and fabrication of detector apparatus. Remote sites where U.S. groups are participating in research include: the Soudan Mine in Minnesota; the Sudbury Mine in Ontario, Canada; the Kamiokande Mine in Japan; the Whipple Observatory and Kitt Peak National Observatory in Arizona; the Pierre Auger Observatory in Argentina; the Cerro-Tololo Inter-American Observatory (CTIO) in Chile; the Apache Point observatory in New Mexico; the Waste Isolation Pilot Project (WIPP) in Carlsbad, New Mexico; the Boulby Mine in the United Kingdom (UK); and the Gran Sasso Underground Laboratory in Italy. Other research supported includes space-based projects such as participation in NASA's Gamma-ray Large Area Space Telescope (GLAST) mission, and the Alpha Magnetic Spectrometer (AMS) led by the Massachusetts Institute of Technology.

Highlights

Recent accomplishments include:

- The Large Area Telescope (LAT), a DOE and NASA partnership and the primary instrument on NASA's GLAST mission, was completed in 2006 and is scheduled for launch from Kennedy Space Center in fall 2007. It will begin full data operations in FY 2008. SLAC led the DOE participation in the fabrication of the LAT and will run the instrument science operations center during the data-taking phase.
- The DOE contribution to the fabrication of the Very Energetic Radiation Imaging Telescope Array System (VERITAS) was completed in 2006, with the telescope installed on a temporary basis at the Whipple Observatory in Arizona, while NSF is completing the arrangement for a permanent site for the final installation. The array will undergo engineering operations at this site through FY 2008 before moving to a permanent site by FY 2009.
- The Cryogenic Dark Matter Search (CDMS II) experiment completed installation of its full complement of 5 kg-sized towers of silicon and germanium detectors in the Soudan Mine in Minnesota beginning in mid-2005. Preliminary results were reported in 2005 from data-taking with two towers (comprising about 2 kg of active detectors), setting new world-record limits on the existence of massive dark matter particles in our galaxy, entering the realm of supersymmetric masses and interaction cross sections. The full experiment will take data through 2007, setting limits about 10 times more sensitive than its existing ones in the search for dark matter particles, well into the realm where new particles are predicted by many models of supersymmetry.

The major planned efforts in FY 2008 are:

- *Operation of the Large Area Telescope,* the primary instrument on NASA's GLAST mission. The goals of the LAT are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including Active Galactic Nuclei and Gamma Ray Bursters, as well as to search for dark matter candidates. It is complementary to the ground-based VERITAS experiment, sampling a lower energy region of the gamma ray spectrum. This research program is being carried out by a collaboration, which includes particle physicists and astrophysicists from SLAC, NASA research centers, the Naval Research Laboratory, U.S. universities, and institutions in Italy, France, Japan, and Sweden.
- *Initial Operations of the VERITAS Telescope Array*. VERITAS is a new ground-based multi-telescope array that will study astrophysical sources of high energy gamma rays, from about 50 GeV to about 50 TeV. The primary scientific objectives are the detection and study of sources that could produce these gamma-rays such as black holes, neutron stars, active galactic nuclei, supernova remnants, pulsars, the galactic plane, and gamma-ray bursts. VERITAS will also search for dark matter candidates. The experimental technique was developed by the DOE/HEP-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. While awaiting installation at its permanent site at Kitt Peak National Observatory, the array is undergoing engineering operations at Whipple Observatory through FY 2008.
- *Fabrication of the Dark Energy Survey (DES) Project.* The FY 2008 request includes a new Major Item of Equipment, the Dark Energy Survey (DES) project. This effort will provide the next step in determining the nature of dark energy, which is causing the universe to expand at an accelerating rate, by measuring the distances to approximately 300 million galaxies. DES employs several methods to measure the effects of dark energy on the distribution of these galaxies and other astrophysical objects. The DES scientific collaboration will begin fabrication of a new charge coupled device (CCD) camera and associated lenses, electronics and data management system to be installed on the Blanco Telescope at the CTIO in Chile. The project is planned as a partnership between DOE and the NSF, which operates the telescope. The scientific collaboration is led by Fermilab and includes participants from laboratories and universities in the U.S., England and Spain. Funding for fabrication in FY 2008 is contingent on successful scientific and technical readiness reviews by the interested funding agencies.
- *R&D for future dark energy experiment(s)*. In order to fully determine the nature of dark energy, the Dark Energy Task Force (DETF), a subpanel of both HEPAP and the Astronomy and Astrophysics Advisory Committee (AAAC) recommended a mix of experiments with independent and complementary measurements. In FY 2008, R&D and/or conceptual design will be performed for proposed experiments that can increase our knowledge of dark energy using ground- or space-based facilities. These facilities could include new detectors on existing ground telescopes, or space-based experiments, such as the SuperNova Acceleration Probe (SNAP) Experiment, a mission concept proposed for a space-based DOE/NASA Joint Dark Energy Mission (JDEM). The DETF report will be used to aid in the development of a coordinated dark energy research program containing specific experiments.
- *Participation in a reactor neutrino experiment*. The FY 2008 request includes U.S. contributions for the design and fabrication of a Major Item of Equipment, a Reactor Neutrino Detector located in Daya Bay, China. This project is supported by a partnership between DOE and research institutes in China. Both the National Academies study and the HEPAP prioritization subpanel (P5) have

identified opportunities in neutrino physics and recommended a reactor-based experiment as part of an overall neutrino research program. This experiment will use anti-neutrinos produced from reactors to precisely measure a crucial parameter needed to pursue new physics opened up by the discovery of neutrino mass and mixing. The value and precision of this parameter will help resolve ambiguities in determinations of other neutrino properties, and will be a key input to determining the directions for further research in the neutrino sector.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
University Research	**17,977**	**17,271**	**18,205**

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 and phenomena.

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 postdoctoral researchers.

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.

In FY 2008, the university program in Non-Accelerator Physics will support several experiments (e.g., VERITAS, Pierre Auger, AMS, and GLAST/LAT) that have completed their fabrication phase in recent years and are moving into operations and data analysis. The detailed funding allocations will take into account the discovery potential of the proposed research. Other research efforts that will be continuing in this subprogram include: KamLAND, an underground neutrino oscillation detector in Japan that detects reactor-produced neutrinos; Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; CDMS-II in the Soudan Mine in Minnesota; a direct search for dark matter particles (ADMX-I) at LLNL; a 200 kg neutrinoless double beta decay experiment (EXO-200) at WIPP; and R&D for ground- and space-based concepts for dark energy experiments. Pre-conceptual R&D will continue on a next-generation dark matter search experiment, including extensions of the CDMS solid-state technology to larger detector sizes (25 kg), and alternative technologies based on liquid or gaseous Xenon detectors. University groups will also participate in the design and R&D efforts for the Dark Energy Survey and the Reactor Neutrino Detector, as described above. Finally, R&D for a larger-scale (about 1,000 kg) neutrinoless double beta decay experiment will be supported. This experiment would measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle. University groups are leading these efforts.

National Laboratory Research	**27,536**	**25,957**	**35,662**

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 experiment design, construction, and operations, in addition to scientists involved in the research. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2008, the laboratory research program in Non-Accelerator Physics will significantly increase in order to support research activities directed at new initiatives in dark energy and neutrino physics (e.g., the Dark Energy Survey and the Reactor Neutrino Detector), and ongoing R&D of next-generation detectors, including a large-scale double beta decay experiment. The laboratory experimental physics research groups will be focused mainly on supporting the instrument science operations center and data-taking and research for the GLAST/LAT telescope ($3,960,000); operations and data analysis for the Pierre Auger cosmic ray detector array and the CDMS-II dark matter detector; operations of ADMX-I and EXO-200; R&D for ground- and space-based concepts for dark energy experiments; analysis of data from Sloan Digital Sky Survey (SDSS) and continued operation of the follow-on SDSS-II.

Approximately 25% of the apparent increase is due to an accounting change at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding categories. The activities supported by these costs include computing support, general engineering and technical support, program management, and business office expenses.

Projects	**8,349**	**15,554**	**17,941**

In FY 2008, this effort will be focused on R&D for the SNAP dark energy mission concept and other potential dark energy experiments; fabrication of the Dark Energy Survey (DES), a Major Item of Equipment (MIE); and R&D and fabrication for the Reactor Neutrino Detector. This activity also included funding for fabrication of the VERITAS telescope, which was completed in FY 2006; telescope operations are funded under the Other activity below. Funding for new MIE projects is contingent on successful scientific and technical readiness reviews by the interested funding agencies.

In the spring of 2006, the Dark Energy Task Force (DETF), a subpanel of both HEPAP and the AAAC, recommended a mix of experiments with independent and complementary measurements to address dark energy. Later in the year, the P5 prioritization subpanel of HEPAP recommended that DOE and NSF jointly pursue the DES project, a small-scale ground-based experiment that can provide significant advances in our knowledge of dark energy in the near term in a cost-effective manner. The FY 2008 request includes $3,610,000 to begin fabrication of DES as a MIE (estimated TEC $15,500,000).

This request also supports R&D for investigating a variety of methods and technologies for dark energy measurements using ground- and/or space-based facilities. The application of this R&D funding will be determined incorporating advice from subpanels of the relevant Federal scientific advisory panels as well as assessment of specific proposals.

As part of this effort, the FY 2008 SNAP R&D activities ($3,500,000) will focus on the conceptual design needed for a potential future space-based mission. NASA's latest "Beyond Einstein" program includes JDEM as one of five proposed Einstein Probe missions. A determination should be made late in 2007 as to which of the five missions will go first. If NASA decides that JDEM will be their first Beyond Einstein mission, the selection of a specific concept for the JDEM mission will take place in 2009. The selected concept would then begin the technical design phase near the end of the decade, leading to fabrication and launch near the middle of the next decade.

The R&D effort to determine technology choices and optimize the detector design for the Reactor Neutrino Detector will continue in FY 2008 ($2,000,000). In addition, MIE funding ($3,000,000) is provided to initiate fabrication (estimated TEC $27,000,000). This experiment will measure a crucial

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

unknown neutrino property by precisely measuring the disappearance of electron antineutrinos generated by the reactor as they travel several hundred meters through the Earth to the underground detector. The MIE project will include the DOE contribution to the fabrication of the experiment. In 2006, HEP, in cooperation with Chinese research institutes, decided to pursue this experiment at a site in Daya Bay, China. The U.S. collaboration is led by groups from BNL and LBNL. The total U.S. TPC for this project will be $29,000,000 per discussions with the Chinese partners.

Other	**343**	**489**	**622**

This category includes funding mainly for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities. It also includes funding for private institutions and other government laboratories and institutions that participate in Non-Accelerator Physics research, including support of the Smithsonian Institute for operations and research using the VERITAS telescope array ($494,000).

Total, Non-Accelerator Physics	**54,205**	**59,271**	**72,430**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
University Research	
The University Research program is maintained at about the FY 2007 level-of-effort to support ongoing non-accelerator-based research.	+934
National Laboratory Research	
The National Laboratory Research program increases significantly, reflecting increased activity in non-accelerator-based research by the national laboratories, particularly in the areas of dark energy, including research on the Dark Energy Survey, SNAP/JDEM, and other concepts; and in cosmology and particle astrophysics at the Kavli Institute at SLAC. About 25% of the apparent increase is due to accounting changes at Fermilab; the remainder is redirection of research effort to the initiatives in non-accelerator-based research program areas.	+9,705
Projects	
Funding increases as the Dark Energy Survey fabrication begins ($+3,610,000) and R&D continues and fabrication begins for the Reactor Neutrino Detector ($+2,000,000). This is offset by a decrease in dark energy R&D funding, including SNAP/JDEM ($-3,223,000).	+2,387

	FY 2008 vs. FY 2007 ($000)
Other	
Resources held pending completion of peer and/or programmatic review increase slightly to be able to respond to new developments.	+133
Total Funding Change, Non-Accelerator Physics	**+13,159**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Theoretical Physics			
University Research	23,404	24,043	24,900
National Laboratory Research	16,590	17,242	20,720
SciDAC	2,670	5,000	5,300
Other	5,320	5,771	5,989
Total, Theoretical Physics	47,984	52,056	56,909

Description

The mission of the Theoretical Physics subprogram is to foster fundamental research in theoretical high energy physics that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Theoretical Physics subprogram provides the vision and mathematical framework for interpreting, understanding, and extending the knowledge of particles, forces, space-time, and the universe. It includes activities ranging from detailed calculations of the predictions of the Standard Model of elementary particles to the extrapolation of current knowledge to a new plane of physical phenomena and the identification of the means to experimentally search for them. The Theoretical Physics subprogram also includes a major effort to incorporate Einstein's theory of gravity and space-time geometry into a unified description of all the forces of nature and cosmology, to illuminate the origin and evolution of the universe. Because theoretical interpretation and analysis underpins almost all progress in HEP, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key questions identified in the HEP Overview section above.

Supporting Information

Though they are typically not directly involved in the planning, 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, and space-time. Our understanding of the universe relies on the active, integrated participation of theorists in interpreting the results of particle physics experiments. The research activities supported by the Theoretical Physics subprogram include: calculations in the quantum field theories of 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 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 activities of the Theoretical Physics subprogram support scientists performing research in theoretical high energy physics and related areas. The research groups are based at approximately 75 colleges and universities and at 6 DOE laboratories (Fermilab, SLAC, BNL, ANL, LBNL, and 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 NSF and NASA. There are also many international collaborations in theoretical physics research. These collaborations are typically smaller and less formal 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.

Scientific Discovery through Advanced Computing

In FY 2005, the HEP program completed the original SciDAC programs in the areas of accelerator modeling and design (Advanced Computing for 21st Century Accelerator Science and Technology), theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (SciDAC Center for Supernova Research and Shedding New Light on Exploding Stars: TeraScale Simulations of Neutrino-Driven Supernovae and their Nucleosynthesis), and applying grid technology (Particle Physics Data Grid Collaborative Pilot). Each of these projects has made significant strides in forging new and diverse collaborations among different disciplines of physics and between physicists and computational scientists; enabling the development and use of new and improved software for large-scale simulations. Examples include the development of algorithms to solve the underlying algebraic equations for multidimensional radiation transport for supernova simulations; the first complete three-dimensional calculation of the complete evolution of a core collapse supernova; the first parallel beam-beam simulation code that includes, in a single application, weak-strong and strong-strong models, finite crossing angle, longitudinal effects, and long-range collisions via a new shifted Green function algorithm; development of a full Applications Programming Interface (API) for running Lattice Gauge calculations on a variety of hardware platforms; and improvement and use of grid technology in running experiments.

To build on these successes, the HEP program re-competed its SciDAC portfolio in FY 2006 to obtain significant new insights through computational science into challenging problems that have the greatest impact in HEP mission areas. Successful new proposals were selected in the areas of theoretical physics, astrophysics, and grid technology. A call for new SciDAC proposals in accelerator modeling and design was issued in December 2006.

Highlights

Recent accomplishments include:

- High precision numerical simulations of the strong interactions of quarks and gluons, Quantum Chromodynamics (QCD), are producing accurate and reliable predictions of strong interaction decay constants and mass differences. These results, which use supercomputer simulations of QCD, include the important but difficult to calculate "virtual quark" effects in the underlying field theory. In some important cases, the agreement between the calculated and experimental values has reached the experimental uncertainty itself. This is a major success of the theory of strong interactions, and is an improvement by nearly an order of magnitude over previous calculations. These breakthroughs have been accomplished by the application of new, highly efficient algorithms combined with the use of today's supercomputers and dedicated clusters of PC's.

- Recently, powerful new techniques have been developed to reliably calculate high-energy strong interaction processes that will be measured at the LHC. These procedures came from studying the most esoteric branch of theoretical high energy physics: "string theory." In traditional calculations, one calculates only one or two of the largest terms in an infinite series; but these new approaches, some of which are based on analytic methods that had their origins in quantum gravity or string theory, calculate the entire infinite set of terms so that more accurate predictions can be made.

By its nature, progress in theoretical physics cannot be predicted in advance. Nevertheless, there are some current major thrusts in theoretical physics that we expect to continue in FY 2008:

- *LHC Phenomenology.* As the start of LHC operations approaches, a greatly increased effort will be made to identify the most promising and sensitive methods for finding signs of new phenomena in the voluminous data that will be produced. Many attractive ideas have been proposed for the solution of fundamental problems such as the mysteries of the origin of the masses of the elementary particles and the mechanisms through which fundamental symmetries are broken in nature. Identifying which ideas are true will entail the calculation of detailed predictions of many suggested models for extensions of the Standard Model.

- *Lattice QCD*. 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 the coupling strength is near zero at very short distances but very strong at large distances (where "large" means the size of an atomic nucleus). 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 some QCD calculations feasible with quite high precision (one to two percent). Some of the computational tools for this effort are provided through the SciDAC program. Progress during FY 2008 will come from the continuation of the major IT investment to procure the necessary computer hardware clusters in partnership with the Nuclear Physics program.

- *New Ideas*. Theoretical physicists are speculating on whether there might be additional space dimensions that are normally hidden from us. These ideas are motivated by the effort to unify Einstein's theory of gravity with quantum mechanics in a mathematically consistent way. It is even possible that some of these dimensions and their consequences are accessible to experiment, perhaps manifesting themselves at the LHC in the production of mini-black holes, or so-called Kaluza-Klein excitations, named after the physicists who first suggested in the 1920's that we actually live in a 5-dimensional universe. Perhaps these ideas can explain the nature of dark matter, or dark energy, or even suggest new cosmologies explaining the history and evolution of the universe.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
University Research	**23,404**	**24,043**	**24,900**

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 postdoctoral researchers. 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.

The theory program addresses 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, currently searching for new physics at the energy frontier, and from the LHC, which will extend the energy frontier when it begins full-power operations. The detailed funding allocations will take into account the involvement of university-based research groups in these targeted physics research activities.

In FY 2008, the university theory program is maintained at about the FY 2007 level-of-effort to support university research personnel participating in analysis of current and previous experiments, and in the design and optimization of new experiments, so that these experiments can fulfill their maximum potential.

National Laboratory Research	**16,590**	**17,242**	**20,720**

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, the laboratory groups are a general resource for the national research program. Through continuing interaction with experimental scientists, they provide a clear understanding of the significance of measurements from ongoing experiments and 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 2008, 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 the Tevatron Collider detectors, CDF and D-Zero, and preparation for the new higher energy data from the LHC. About 80% of the increase is due to accounting changes at Fermilab which result in direct support costs being charged to the Theoretical Physics subprogram. In FY 2008, actual funding for the laboratory theory program will be maintained at about the FY 2007 level-of-effort to support laboratory research personnel participating in analysis of current and previous experiments, and design and optimization of new experiments, so that these experiments can fulfill their potential to make new discoveries about the nature of the universe.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
SciDAC	**2,670**	**5,000**	**5,300**

In FY 2008, HEP will continue support for successful new proposals selected in the re-competition of the SciDAC program in FY 2006, as well as any successful new proposals solicited in FY 2007. Proposals are selected based on peer review. In FY 2006 there were three principal new HEP-supported SciDAC efforts in the areas of Type Ia supernova simulations (to generate supernova light curves appropriate for dark energy measurements); platform-independent software to facilitate large-scale QCD calculations (see Other below); and very large scale, fault-tolerant data handling and "grid" computing that can respond to the serious data challenges posed by modern HEP experiments. Funding in FY 2006 was for a six-month period only as the awards were made late in the fiscal year; funding in FY 2007 and beyond will be for the full twelve-month period.

Other	**5,320**	**5,771**	**5,989**

This activity includes funding for the Lattice QCD Computer Program, as well as for education and outreach activities, compilations of HEP data and reviews of data by the Particle Data Group at LBNL, conferences, studies, workshops, funding for research activities that have not yet completed peer review, and responding to new and unexpected physics opportunities.

A coordinated effort with the Nuclear Physics and Advanced Scientific Computing Research programs is aimed toward the development of a multi-teraflops computer facility for Lattice QCD simulations. During FY 2006, a joint effort with NP to develop a dedicated Lattice QCD facility with about 13 teraflop capacity was started, and in FY 2008 this program will proceed as planned.

In each year of the Lattice QCD investment, procurement of computers employing the most cost-effective option will be undertaken. Given current projections of price performance for this kind of high-performance computing, commodity clusters are the most effective investment. The HEP contribution of $2,000,000 to this effort in FY 2008 will correspond to about 3 teraflops of sustained computing performance, in addition to 6.5 teraflops of computing power acquired in previous years.

This category also includes support for the QuarkNet education project ($795,000). This project takes place in QuarkNet "centers" which are set up at universities and laboratories around the country. The purpose of each center is to allow students to understand and analyze real data from an active HEP experiment (such as the Tevatron or LHC experiments). Each center has 2 physicist mentors and, over a 3 year period, goes through several stages to a full operating mode with 12 high school teachers. The project began in 1999 with an initial complement of 12 centers starting in the first of three yearly stages of development. The full complement of 52 centers, with 625 teachers, was in place in FY 2004. Several centers have retired and new ones have started in the last few years. In FY 2008, most of the centers will be in stage 3, which is the full operations mode. QuarkNet operations will continue through the life of the LHC program at CERN.

Total, Theoretical Physics	**47,984**	**52,056**	**56,909**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
University Research	
University Research is maintained at about the FY 2007 level-of-effort to support university researchers participating in analysis of current and previous experiments, and design and optimization of new experiments.	+857
National Laboratory Research	
About 80% of the increase is due to accounting changes at Fermilab which result in direct support costs being charged to the Theoretical Physics subprogram. The remainder is a modest increase to support national laboratory researchers participating in analysis of current and previous experiments, and in the design, optimization, and analysis of new experiments.	+3,478
SciDAC	
Funding for the SciDAC program is increased to maintain an approximately constant level-of-effort for proposals that were successful in the re-competition of the HEP SciDAC portfolio in FY 2006 and FY 2007.	+300
Other	
Reflects an increase in funds held for theoretical physics activities, including conferences and workshops, pending completion of peer and/or programmatic review.	+218
Total Funding Change, Theoretical Physics	**+4,853**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Advanced Technology R&D			
Accelerator Science	27,355	33,016	41,004
Accelerator Development	72,050	88,030	107,591
Other Technology R&D	22,196	18,568	14,962
SBIR/STTR	—	19,862	19,907
Total, Advanced Technology R&D	121,601	159,476	183,464

Description

The mission of the Advanced Technology R&D subprogram is to foster world-leading research into the science of particle accelerators, as well as particle acceleration and detection techniques and instrumentation. These in turn provide enabling technologies and new research methods to advance scientific knowledge in a broad range of energy-related fields, including high energy physics, thereby advancing the DOE's strategic goals for science.

Benefits

The Advanced Technology R&D subprogram provides the technologies needed to design and build the accelerator and detector facilities used to carry out the experimental program essential to accomplish the programmatic mission in high energy physics. This is accomplished by supporting proposal driven, peer reviewed research in the fundamental sciences underlying the technologies used for HEP research facilities. These efforts focus on new concepts and inventions and their reduction to practice; that is, developing new technologies to the point where they can be successfully incorporated into construction projects that will significantly extend the research capabilities. Because accelerator and detector R&D underpins almost all progress in HEP experimental research, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key questions identified in the HEP Overview section.

The Advanced Technology R&D subprogram includes not only R&D to bring new accelerator and detector concepts to the stage where they can be considered for use in existing or new facilities, but also advancement of the basic sciences underlying the technology. Most of the technology applications developed for high energy physics that prove useful to other science programs and to industry, flow from the work carried out in this subprogram.

Supporting Information

High energy physics research is strongly dependent on the use of high energy particle beams provided by charged particle accelerators, storage rings, and their associated detectors. 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 little or 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. Since in many cases the same technologies find applications to synchrotron light sources, intense neutron sources, very short pulse, high brightness electron beams, and computational software for accelerator and charged particle beam optics design, they are widely used in nuclear physics, materials science, chemistry, medicine, and industry.

Accelerators have migrated into general usage for medical therapy and diagnostics, and for preparation of radionuclides used in medical treatment facilities, electronics and food industries. They are also now finding homeland security applications.

Possible future accelerators were one of the main concerns of the recent National Academies study of high-energy physics. This study[a] recommended that the U.S. HEP program "plan and initiate a comprehensive program to become the world-leading center for research and development on the science and technology of a linear collider." The same goal has been re-affirmed by HEPAP. The FY 2008 request includes a major effort to ensure that the U.S. is among the leaders in all aspects of the International Linear Collider (ILC), with a strong emphasis on technology R&D, not only for the ILC, but also for a diverse array of other world-leading efforts in technology development that has a broad range of science applications.

Active world-wide, inter-regional cooperation on linear collider accelerator systems, physics studies, and detector development has been underway for the past decade. The International Linear Collider Steering Committee (ILCSC) coordinates scientific and organizational aspects of the activities directed toward an international proposal to construct a linear collider. These activities include establishing a standard set of operating parameters and organizing an international collaboration. The ILCSC also selected superconducting radiofrequency accelerating cavities as the preferred technology for the main ILC Linac. The international Global Design Effort (GDE) was established to coordinate and provide leadership in the international R&D effort. The GDE has delivered a baseline configuration document for the ILC, established a controlled configuration change process, and is developing a reference ILC design and cost to be released in February 2007. The cost provided at that time will be in currency-free value units so that each country can do a translation into its own currency using its accounting standards and procedures.

The ILC reference design process will include a preliminary cost estimate, first steps to industrialization of the components, development of sample sites in the U.S. and elsewhere, and physics detector concepts. In parallel with the steps taken toward reaching a design for the ILC, an informal ad hoc group of senior science program officials from funding agencies in a dozen developed nations has been formed to provide support for the GDE and discuss how one might formally organize a future ILC project, should a decision be made to go forward, as well as coordinating other proposed large scale international facilities.

Future electron and proton accelerators are expected to be based upon the superconducting radiofrequency (RF) acceleration technology pioneered by HEP researchers, which is now being applied in nuclear physics, basic energy sciences, biology, and fusion facilities. Further development of this technology can enable cost reductions and enhanced capability across the broad spectrum of SC programs.

---

[a] *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics* (aka "EPP2010"), National Academies Press, 2006. Available online at http://www7.nationalacademies.org/bpa/EPP2010.html

Accelerator Science

The Accelerator Science activity in this subprogram focuses on the science underlying the technologies used in particle 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 the latter include standards for testing of advanced superconducting materials, instrumentation standards, the physics of charged particle beams and optics, and user facilities for general support of accelerator research, such as the Accelerator Test Facility (ATF) at BNL.

Accelerator Development

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. Included in this activity is work on developing very high field superconducting magnet technology, studies of very high intensity proton sources for potential application in neutrino physics research or heavy ion studies, and muon accelerator proof-of-principle research. When concepts develop enough to be viewed as part of a larger system, or as potentially leading to a proposal for a construction project, they are given special attention. The ILC is the current R&D activity in this area.

Other Technology R&D

This category includes funding at universities under Advanced Detector Research and at national laboratories under Detector Development. Advanced Detector Research is similar to Accelerator Science in that it addresses the development and application of an underlying science to foster new technologies in particle detection, measurement, and data processing. 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:

- There has been significant progress on alternate physical mechanisms of charged particle acceleration. In particular, current experiments at SLAC address the potential feasibility of a particle-driven plasma wakefield "afterburner" that could one day potentially double the energy of a linear accelerator beam in only a few meters of plasma. An accelerating gradient 1,000 times that now possible in conventional accelerators has been measured in an 85 centimeter long plasma channel for a net energy gain in excess of 40 GeV. The acceleration of positrons (anti-electrons) by particle driven plasma wake fields has also been demonstrated, an essential step if the plasma accelerators are to ever be applied to electron-positron colliders.
- At LBNL, a laser-driven plasma wakefield experiment has successfully trapped a bunch of electrons in a plasma and accelerated them to energies of 1 GeV in a few millimeters. The process creates an electron bunch in which the distribution of individual electron energies is very narrow, within a few percent of the average energy of the bunch. This is an important step forward from the earlier experiments that produced bunches with 100% energy spread and is an essential step in developing a useful accelerator.

The major Advanced Technology R&D efforts in FY 2008 are:

- *International Linear Collider R&D.* A TeV scale linear electron-positron collider has been identified by the recent National Academies' "EPP2010" study as "the essential component of U.S. leadership in particle physics in the decades ahead." In FY 2008, the R&D activities addressing critical performance and cost issues will be expanded on a coordinated international basis and steps will be taken to industrialize the key components. The ILC R&D program in FY 2008 supports a strong U.S. role in a comprehensive and coordinated international R&D program, and provides the basis for U.S. industry to compete successfully for major subsystem contracts, should the ILC be built. The work needed to develop U.S. leadership in various technical areas will be continued. A strong international collaborative design effort, conducted under an international memorandum of understanding, will proceed.

  The Department will consult with our international partners about entering into formal negotiations to establish an international agreement to direct the engineering design phase of the proposed ILC, should the U.S. and partner governments choose to proceed to a fully-costed engineering design for the project. This agreement would be similar in spirit to the ITER Engineering Design Activities (EDA) agreement (http://www.iter.org/EDA.htm). The information provided by the activities would inform future decisions on the construction of and U.S. participation in the proposed ILC.

- *Research and Development of Superconducting RF technology.* A broad spectrum of SC programs need a rigorous research and development program and domestic industrial capability, not presently available, to produce cost competitive and reliable superconducting RF components for possible future accelerators that serve the science mission. The industrial development will require extensive testing capability in our national laboratories to stimulate new techniques, to demonstrate the quality of commercial products and to feed back crucial information needed for process improvements and quality control. This growing R&D effort is now separately tracked and reported in the FY 2008 request.

- *Accelerator Science.* The pursuit of new acceleration concepts at universities and laboratories will be intensified to develop more options for future high-energy accelerators beyond the ILC. New concepts will be explored through simulations, and promising candidates will be tested with experiments at universities and at laboratory-based user facilities. The test capabilities of user facilities will be enhanced and operation will be expanded to meet user demand.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Accelerator Science	**27,355**	**33,016**	**41,004**
▪ **University Research**	**9,527**	**13,037**	**16,556**

The increase in funding in FY 2008 will support a renewed university research program in advanced accelerator physics and related technologies. The research program will continue to pursue development of niobium-tin and similar superconductors and their application, as well as R&D in the application of high temperature superconductors; investigations of the use of plasmas and lasers to accelerate charged particles, which will focus on the use of laser driven plasma wakefields; development of novel high power radiofrequency (RF) sources for driving accelerators and for conducting high gradient research including studies of vacuum breakdown phenomena and material

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

properties; and R&D into the issues of much higher accelerating gradient in RF superconductors. 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 will also be continued. Accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams is included in this effort and will be continued.

The FY 2008 budget will continue the expanded university accelerator science program begun in FY 2007 at a level that can provide support needed for enhanced long-term R&D, in parallel with overall program increases aimed at nearer-term R&D for future facilities. New research initiatives, including an expanded program in the physics of very high accelerating gradients, will continue to be supported. Funds will also be directed at bringing the research infrastructure at some of the small university-based facilities up-to-date.

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, participation in conferences, and publications.

▪ **National Laboratory Research**	**16,398**	**18,323**	**22,676**

There are areas of Accelerator Science research that require the more extensive or specialized research facilities located at DOE national laboratories. 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 includes the annual HEP program review supported by well-qualified peers, publications in professional journals, and participation in conferences and workshops.

BNL is the home of the very successful Accelerator Test Facility (ATF), supporting research that HEP funds at universities and in industry including research funded through the Small Business Innovation Research (SBIR) Program. In FY 2008, the ATF will continue a program of testing advanced accelerator concepts, developing new instrumentation, and developing next generation high brightness electron sources based on laser-driven photocathodes. R&D on the muon production target experiment at CERN will also be funded.

The Center for Beam Physics at LBNL is supported in FY 2008 for research in laser-driven plasma acceleration, advanced RF systems, laser manipulation and measurement of charged particle beams, and a broad program in instrumentation development, accelerator theory, and computation. R&D on muon ionization cooling and theoretical studies of alternative muon acceleration schemes will also be carried out.

Fermilab maintains a small advanced accelerator R&D program focused on high-brightness photoinjectors and research on muon acceleration. In previous years this effort was reported under Accelerator Development (see below); in FY 2008 it is captured under Accelerator Science to improve consistency of reporting with other laboratory accelerator R&D programs. As a result, most of the funding increase in National Laboratory Accelerator Science Research in FY 2008 is due to this reclassification. The overall FY 2008 request for laboratory advanced accelerator research activities is maintained at about the FY 2007 level-of-effort, excluding the Fermilab reclassification described above. In FY 2008, R&D in support of the international muon cooling collaboration with

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Rutherford Appleton Laboratory in the UK will continue. Fermilab is the lead laboratory for R&D and test infrastructure needed to develop superconducting RF electron- and proton-based accelerators for a wide range of applications, as outlined above.

The advanced accelerator R&D program at SLAC in FY 2008 will continue to support R&D into advanced particle acceleration technologies, and work with BES on R&D for new experimental capabilities at SLAC that take advantage of the unique qualities of the Linac beam. R&D into ultra high-frequency microwave systems for accelerating charged particles will be focused on high field breakdown phenomena and new accelerating geometries that support very high gradients. Very advanced electron-positron collider concepts and theoretical studies in advanced beam dynamics methods and new computer computation and simulation codes will continue. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the Accelerator Science activity.

Other activities supported in FY 2008 include theoretical studies of space-charge dominated beams at PPPL and research on new means of generating high-brightness electron beams, and the use of charged particle wakefields to generate microwaves for particle acceleration at ANL.

▪ **Other**	**1,430**	**1,656**	**1,772**

This subactivity includes funding for Accelerator Science at sites other than universities and national laboratories. These include interagency agreements with NRL and the National Institute of Standards and Technology (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.

Accelerator Development	**72,050**	**88,030**	**107,591**
▪ **General Accelerator Development**	**28,250**	**23,130**	**24,136**

This research includes R&D to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities, used in upgrading existing facilities, or applied to the design of new facilities. The work is mostly done at Fermilab, LBNL, SLAC, and BNL, with supporting activities at TJNAF, ANL, LLNL, and LANL. The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; stochastic and electron cooling technologies; beam dynamics, both linear and nonlinear; and development of large simulation programs. Research on superconducting RF acceleration systems and related RF power systems was previously included in this subactivity but is now reported separately below.

The R&D program at Fermilab in FY 2008 will address a broad spectrum of technology needs for that facility, including advanced superconducting magnet R&D, R&D for a high-intensity neutrino beam facility, advanced beam instrumentation, and simulation codes to provide improved modeling of all aspects of accelerator operations.

The LBNL R&D supported in FY 2008 includes work on very high field superconducting magnets using niobium-tin and similar superconductors, on new beam instrumentation for use at Fermilab and SLAC, and on extensive beam dynamics and simulation studies with particular emphasis on the electron cloud instability and related efforts in proton and electron colliders. The very successful

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

industrially-based program to develop advanced superconductors, particularly niobium-tin, for the very high field superconducting magnet R&D program will continue to be supported.

The FY 2008 program at SLAC encompasses high-powered RF systems, beam instrumentation, generic electron-positron collider R&D, and advanced beam dynamics and machine simulation code development. Simulation codes for modeling RF system components and high-powered microwave tubes will receive special R&D focus.

The R&D program at BNL includes work on superconducting magnet R&D and associated superconducting magnet materials measurement facility.

In FY 2008, the national laboratory program is maintained at about the FY 2007 level. The funding increase is due to accounting changes at Fermilab that move costs for direct program support from Operations to Research and Technology R&D funding activities. The areas supported by these costs include computing support, general engineering and technical support, program management and business office expenses.

	FY 2006	FY 2007	FY 2008
▪ **Superconducting RF R&D**	**14,100**	**4,900**	**23,455**

Because of increasing emphasis on superconducting RF technology for accelerators, and its potential application to a broad range of SC programs, R&D on superconducting RF acceleration systems and related RF power systems is now separately reported in this request.

In FY 2008, this effort will provide funds to make industrial procurements of prototype accelerating cavities, high power RF input couplers, and RF power klystrons and modulators. This request also enables development of U.S. capability for testing individual bare cavities, and dressed cavities with all power components attached. Separate test stands are needed to develop the high power RF systems that feed the accelerating cavities. Test areas for accelerating systems will be built upon existing infrastructure at Fermilab, ANL, TJNAF, LANL, and Cornell University. Those supporting the RF power system tests will be located at SLAC and LLNL. Fermilab is the lead U.S. laboratory coordinating the national R&D program in this area.

	FY 2006	FY 2007	FY 2008
▪ **International Linear Collider R&D**	**29,700**	**60,000**	**60,000**

The International Linear Collider (ILC) as currently conceived will collide beams of electrons and positrons head-on at very high energies (500 GeV–1 TeV). This will permit precise and clean measurements of currently undiscovered particles and forces.

Panels worldwide have all strongly recommended that the ILC is the tool that is needed to make the next scientific steps forward after the LHC starts operations in Europe in 2007. There are powerful reasons to believe that the LHC could open the door to a new domain of particles and forces. Building a coherent and compelling understanding that describes these particles and forces will require the precise and clean measurements that the ILC can provide. For example, the ILC would answer questions such as: Is one of these new particles stable, with properties consistent with the cosmic dark matter that makes up a quarter of the universe? Is whatever is found at the LHC really the long sought after Higgs boson? Does it give mass to the other particles? Are the particles found at the LHC related to those we already know through a newly discovered symmetry of nature?

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2007, the ILC international collaboration under the direction of the Global Design Effort will complete a detailed review of the R&D to be accomplished world wide, milestones and priorities for that work, a pre-conceptual design document, and cost estimate. These documents will be submitted to the sponsoring governments for review, and will serve as the basis for the detailed design study that will proceed in FY 2008.

The Department will consult with our international partners about entering into formal negotiations to establish an international agreement to direct the engineering design phase of the proposed ILC, should the U.S. and partner governments choose to proceed to a fully-costed engineering design for the project. This agreement would be similar in spirit to the ITER Engineering Design Activities (EDA) agreement (http://www.iter.org/EDA.htm). The information provided by the activities would inform future decisions on the construction of and U.S. participation in the proposed ILC.

Starting in FY 2007, all ILC funding was consolidated in this budget category including both accelerator and detector R&D efforts, as well as support of GDE management activities (see Detector Development below).

In FY 2008, the U.S. collaboration will continue to focus its R&D efforts on developing the electron and positron sources, the damping rings needed to prepare the high brightness beams and the high-gradient accelerating components associated with the main Linacs. R&D will continue on designing and testing the critical elements needed to bring the beams into collisions and developing the instrumentation for monitoring the beam properties. Particular attention will be given to R&D aimed at cost reduction and value engineering of present baseline systems, and developing alternate low-risk components with prospects for cost reduction, where appropriate. Work will continue on developing the machine controls and large-scale simulations of the full accelerator complex.

The detailed design, aimed at a complete Technical Design Report in 2009, will be conducted throughout FY 2008 in collaboration with our international partners through the newly created international EDA agreement. R&D on critical components for the experimental detectors will be conducted to position U.S. scientists for leadership in the ILC scientific program. Prototype calorimeter and tracking systems will be studied in the Fermilab test beam, providing a major test of particle flow algorithms and detector construction techniques.

A detailed set of site requirements will be developed in FY 2007 and published by the GDE. To prepare for a potential U.S. bid to host the ILC, should it be built, detailed conventional construction studies related to potential U.S. site(s) will be performed in FY 2008. Site specific studies relating to geological conditions, environmental and safety impact, and machine design issues that arise at a specific site are needed by about the end of FY 2008 to permit completion of the technical design report in the succeeding year.

Other Technology R&D	**22,196**	**18,568**	**14,962**
▪ **Advanced Detector Research**	**836**	**1,421**	**1,469**

The Advanced Detector Research (ADR) program supports university physicists to develop new detector technologies, or technology advances which would be generally applicable to a wide range of HEP experiments. The chosen technologies are motivated by the needs of conceptually foreseen but not yet developed experimental applications. Approximately six to eight grants a year are

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

awarded through a competitive peer review program. Final funding levels will depend on the number and quality of proposals received. This program complements the detector development programs of the national laboratories.

The FY 2008 request reflects the continued interest of the HEP community in early-stage detector development aimed at the detection challenges of new experimental initiatives. The challenges posed by new accelerator and non-accelerator based experiments drive the need for: tolerance to high radiation environments, high resolution detectors with very fast readouts, lower-cost implementations of existing technologies, and novel detection techniques.

▪ **Detector Development**	**21,003**	**13,628**	**13,493**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories and about 40 universities to advance these technologies to a point where there is reasonable chance that an experiment can adopt the technology successfully. Current areas of investigation include R&D on detector technologies that could be used to pursue new opportunities in particle astrophysics and neutrino physics. In FY 2006 these efforts included funds ($5,848,000) for detector R&D related to the International Linear Collider (ILC) program, coordinated with the NSF; ILC-related detector R&D is included in the ILC R&D budget subactivity above in FY 2007 and FY 2008.

The FY 2008 request will maintain R&D efforts directed toward developing new detectors including much needed prototyping and in-beam studies. A diverse program applicable to dark matter and dark energy studies, as well as accelerator-based programs will be continued, including efforts on particle flow calorimeters, liquid noble gas detectors, transducer technology (e.g., advanced charged-coupled devices, silicon photomultipliers), and radiation resistant, fast readout electronics.

▪ **Other**	**357**	**3,519**	**—**

This subactivity included funding for research activities that had not yet completed peer review, or to respond to new and unexpected physics opportunities. In FY 2006 and FY 2007, targeted efforts were funded to develop new accelerator and detector concepts related to neutrino physics. In FY 2008, these activities have transitioned out of the R&D stage as new experiments have begun fabrication and are funded largely in the Proton Accelerator-Based Physics subprogram (NOνA and T2K).

SBIR/STTR	**—**	**19,862**	**19,907**

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) set-asides are mandated by Congress. The HEP program manages 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 based on material provided in response to an annual HEP solicitation for suggestions from scientists and engineers in universities and DOE national laboratories working in support of the HEP Advanced Technology R&D programs. There is also coordination with the DOE Nuclear Physics and Fusion Energy Sciences programs concerning areas of mutual interest. The selection of the R&D topics to be included in the annual solicitation is treated as an important and

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

integral component of the advanced accelerator R&D program, and selections of grants are made based on a combination of the recommendations of the peer reviewers and the importance to the HEP programs in Accelerator Science and Accelerator Development. In FY 2006, $16,479,000 was transferred to the SBIR program and $1,977,000 was transferred to the STTR program.

Total, Advanced Technology R&D	**121,601**	**159,476**	**183,464**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Accelerator Science	
▪ The increase in funding in FY 2008 will support a renewed and expanded University Research program in advanced accelerator physics and related technologies.	+3,519
▪ Most National Laboratory Research activities are maintained at about the FY 2007 level-of-effort ($+403,000). The rest of the funding increase in FY 2008 ($+3,950,000) is due to the reclassification of Fermilab R&D efforts into this subactivity from General Accelerator Development.	+4,353
▪ Other resources held pending completion of peer and/or programmatic review increase slightly to be able to respond to new developments.	+116
Total, Accelerator Science	**+7,988**
Accelerator Development	
▪ General Accelerator Development efforts are held at approximately the FY 2007 level. The funding increase is due to accounting changes at Fermilab that moves costs for direct program support from Operations to Research and Technology R&D funding activities.	+1,006
▪ The increase in Superconducting RF technology provides funds to support research and development for possible future accelerators and enables development of superconducting RF test capabilities at national laboratories and universities, supporting the needs of a full range of future applications.	+18,555
Total, Accelerator Development	**+19,561**
Other Technology R&D	
▪ Advanced Detector R&D efforts increase slightly to reflect anticipated proposal levels in this area of R&D. Final funding levels will depend on the number and quality of proposals received.	+48

	FY 2008 vs. FY 2007 ($000)
▪ Detector development funding decreases slightly to reflect anticipated proposal levels in this area of R&D. Final funding levels will depend on the number and quality of proposals received.	-135
▪ Other R&D funding decreases as targeted R&D activities for neutrino physics have transitioned out of the R&D stage, and new experiments have begun fabrication and are funded in other subprograms of the HEP request.	-3,519
Total, Other Technology R&D	**-3,606**
SBIR/STTR	
The changes reflect the mandated funding for the SBIR and STTR programs.	+45
Total Funding Change, Advanced Technology R&D	**+23,988**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Construction			
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	—	10,300[a]	—

Description

This subprogram provides for the Construction and Project Engineering and Design that is needed to meet overall objectives of the High Energy Physics program.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	**—**	**10,300[a]**	**—**

The Electron Neutrino Appearance (EνA) Detector is a very large detector, to be fabricated by Fermilab and collaborating universities, which would be sited in northern Minnesota. The EνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget but has been reconfigured as a MIE to reflect a revised acquisition strategy for this project that does not require DOE to fund the associated civil construction activities. See the Detailed Justification under the Proton Accelerator-based Physics subprogram for MIE details.

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	
The EνA detector was originally proposed as a line-item construction project in the FY 2007 Congressional Budget but has been reconfigured as a MIE to reflect a revised acquisition strategy for this project. Thus, line-item construction funding is not requested for FY 2008.	-10,300

[a] EνA detector, proposed as a line-item construction project in the FY 2007 Congressional Budget has been reconfigured as a MIE under project name NOνA to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	13,135	15,495	12,635
Accelerator Improvement Projects	7,800	—	2,900
Capital Equipment	52,228	39,927	55,766
Total, Capital Operating Expenses	73,163	55,422	71,301

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unappro-priated Balance
07-SC-07, Electron Neutrino Appearance (EνA) Detector, PED	10,300	—	—	10,300[a]	—	—

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
Large Hadron Collider– ATLAS Detector, CERN (01CA)	102,950[b]	55,549	53,105	1,598	846	—	FY 2007
Large Hadron Collider– CMS Detector, CERN (01CB)	147,050[c]	71,789	67,639	2,900	1,250	—	FY 2007
Very Energetic Radiation Imaging Telescope Array System (VERITAS), Amado, Arizona (41NF)	7,399[d]	4,799	3,650	1,149	—	—	FY 2006
BaBar Instrumented Flux Return (IFR) Upgrade, SLAC (41NQ)	4,900	4,900	4,200	700	—	—	FY 2006

[a] The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer the EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.
[b] The total U.S. contribution (TPC) for this project is $163,750,000, including $60,800,000 from NSF.
[c] The total U.S. contribution (TPC) for this project is $167,250,000, including $20,200,000 from NSF.
[d] The total TPC for this project is $17,534,000 including $7,333,000 from NSF, $2,000,000 from the Smithsonian Institution, and $802,000 from foreign partners. NSF is completing the arrangements for a permanent site.

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
Reactor Neutrino Detector, Daya Bay, China	29,000[a]	27,000	—	—	3,000[a]	3,000	FY 2011
NuMI Off-axis Neutrino Appearance (NOνA) Detector, Fermilab	260,000[bc]	155,200	—	—	—[d]	4,900	FY 2012
Dark Energy Survey, Cerro-Tololo Inter-American Observatory, Chile	20,000[b]	15,500	—	—	—	3,610	FY 2011
Main Injector Experiment ν–A (MINERνA), Fermilab	15,000[e]	10,000	—	—	—	5,000	FY 2010
Tokai-to-Kamioka (T2K) Near Detector, Tokai, Japan	4,700[f]	3,000	—	—	—	2,000	FY 2009
Total, Major Items of Equipment				6,347	5,096	18,510	

[a] The total U.S. TPC for this project will be $29,000,000 per discussions with the Chinese partners. The Department plans to submit a request when the FY 2007 appropriation is enacted to reprogram $3,000,000 of MIE funds towards ongoing R&D for the Daya Bay detector. No funding will be used for fabrication until approval and validation of the Performance Baseline and approval of Start of Construction in FY 2008.

[b] No funding will be used for fabrication until approval and validation of the Performance Baseline and approval of Start of Construction.

[c] The TPC of the project includes NuMI proton improvements as described under the Proton Accelerator-Based Physics subprogram and will not exceed $260,000,000.

[d] The EνA detector was originally proposed as a line-item construction project ($10,300,000) in the FY 2007 Congressional Budget but has been renamed NOνA and has been reconfigured as a MIE to reflect a revised acquisition strategy that requires associated civil construction activities to be funded by a financial assistance agreement with a participating research institution. The Department plans to submit a reprogramming request when the FY 2007 appropriation is enacted to transfer EνA construction funds to operating funding under Proton Accelerator-Based Physics for the NOνA MIE, including TEC of $2,300,000 and OPC of $8,000,000.

[e] Mission Need (CD-0) was approved June 2006 with a TPC range of $10,000,000-$15,000,000. The baseline TPC will be approved at CD-2 (Approve Performance Baseline). The FY 2008 Budget Request is for engineering design only. Engineering design may include limited fabrication and testing of design concepts. Funds for full fabrication will be requested after validation of Performance Baseline.

[f] Preliminary estimated DOE TEC and TPC are shown. No funding will be used for fabrication until approval and validation of the Performance Baseline and approval of Start of Construction.

Nuclear Physics

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Nuclear Physics			
Medium Energy Nuclear Physics	103,161	122,781	123,379
Heavy Ion Nuclear Physics	156,657	197,512	203,188
Low Energy Nuclear Physics	67,106	83,899	90,647
Nuclear Theory	28,352	35,348	36,405
Subtotal, Nuclear Physics	355,276	439,540	453,619
Construction	2,480	14,520	17,700
Total, Nuclear Physics	357,756[a]	454,060	471,319

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the Nuclear Physics (NP) program is to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy and develop the scientific knowledge, technologies and trained workforce 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.

Benefits

The Office of Science's (SC) Nuclear Physics program will substantially advance our understanding of nuclear matter and the early universe. It will help the United States maintain a leading role in nuclear physics research, which has been central to the development of various technologies, including nuclear energy, nuclear medicine, and national security. The highly trained scientific and technical personnel in fundamental nuclear physics that are a product of the program are a valuable human resource for many applied fields.

---

[a] Total is reduced by $3,707,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $8,284,000, which was transferred to the SBIR program; and $994,000, which was transferred to the STTR program. The funding allocation also reflects an approved reprogramming moving $500,000 from the Medium Energy Nuclear Physics subprogram to Construction to begin Project Engineering and Design for the 12 GeV Upgrade project at the Continuous Electron Beam Accelerator Facility.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus 16 Strategic Goals that tie to the Strategic Themes. The NP program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

The NP program has one GPRA Unit Program Goal which contributes to Strategic Goal 3.1 and 3.2 in the "goal cascade."

GPRA Unit Program Goal 3.1/2.47.00—Explore Nuclear Matter - from Quarks to Stars—Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks and gluons, to the stable elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability and possess radically different properties from known matter.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The NP subprograms (Medium Energy, Heavy Ion, Low Energy, and Nuclear Theory) contribute to these Strategic Goals by supporting innovative, peer-reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, and in particular, to investigate the fundamental forces that hold the nucleus of the atom together, and determine the detailed structure and behavior of atomic nuclei. The Nuclear Physics program contributes by building and supporting world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda. Scientific discoveries at the frontiers of nuclear physics further the Nation's energy-related research capacity, which in turn, provides for the Nation's security, economic growth and opportunities, and improved quality of life. In developing strategies to pursue these exciting research opportunities, the Nuclear Physics program is guided by the present long-range planning report prepared by its primary advisory panel, the Nuclear Science Advisory Committee (NSAC)—Opportunities in Nuclear Science (2002). NSAC is in the process of generating a new long-range plan for nuclear science, due by the end of 2007. The program is also cognizant of opportunities expressed elsewhere; e.g., Connecting Quarks with the Cosmos (2003), a report prepared by the National Research Council and sponsored by DOE, the National Science Foundation (NSF), and National Aeronautics and Space Administration (NASA), and the interagency response to this report, The Physics of the Universe, a Strategic Plan for Federal Research at the Intersection of Physics and Astronomy, prepared by the National Science and Technology Council. The program will be informed by the advice of the National Academies concerning the scientific opportunities with rare isotope beams; a final report from the National Academies will be published in spring 2007. The program is consistent with both the DOE and SC Strategic Plans.

The Medium Energy subprogram will contribute to Strategic Goals 3.1 and 3.2 by investigating the quark and gluon substructure inside the nucleon. Although protons and neutrons can be separately observed, their quark constituents cannot be because they are permanently confined inside the nucleons. Measurements are carried out primarily using electron beams with the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF, or JLab) and using polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven

National Laboratory (BNL), as well as other facilities worldwide. The following indicator establishes a specific long-term goal in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- making precision measurements of fundamental properties of the proton, neutron, and simple nuclei for comparison with theoretical calculations to provide a quantitative understanding of their quark substructure.

The Heavy Ion subprogram will contribute to Strategic Goals 3.1 and 3.2 by searching for the predicted novel forms of matter and other new phenomena that might occur in extremely hot, dense bulk nuclear matter. The quarks and gluons that compose each proton and neutron are normally confined within these nucleons. However, if nuclear matter is compressed and heated sufficiently, quarks should become deconfined: individual nucleons will melt into a hot, dense plasma of quarks and gluons. Such plasma is believed to have filled the universe about a millionth of a second after the "Big Bang." Measurements are carried out primarily using relativistic heavy-ion collisions at RHIC. Important measurements will also be made at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN). The U.S. participation in the heavy ion program at the LHC will provide researchers the opportunity to search for new states of matter under substantially different initial conditions than those provided by RHIC, yet still provide a piece of the puzzle regarding the matter that existed during the infant universe. The following indicator establishes a specific long-term goal in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- searching for, and characterizing the properties of, the quark-gluon plasma by briefly recreating tiny samples of hot, dense nuclear matter.

The Low Energy subprogram will contribute to Strategic Goals 3.1 and 3.2 by investigating nuclei at the limits of stability, nuclear astrophysics, the nature of neutrinos, and fundamental symmetry properties in nuclear systems. The coming decade in nuclear physics may reveal new nuclear phenomena and structure unlike anything known from the stable nuclei of the world around us. Nuclear physics research is essential if we are to solve important problems in astrophysics—the origin of the chemical elements, the behavior of neutron stars, the origin of the highest-energy cosmic rays, core-collapse supernovae and the associated neutrino physics, and galactic and extragalactic gamma-ray sources. Measurements of nuclear structure and nuclear reactions are carried out primarily at the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) and the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). Neutrinos are elusive particles that permeate the universe and hardly interact with matter, yet are believed to play a key role in the explosion of stars. Recent experiments have shown that a neutrino oscillates among all of its three known types as it travels from its source—something that can only happen if neutrinos have tiny masses. Studies to better understand the properties of neutrinos, and in particular their masses, are primarily carried out with specialized detectors located deep underground or otherwise heavily shielded against background radiation. Measurements of symmetry properties, particularly of the neutron, are being developed by nuclear physicists at the Spallation Neutron Source (SNS) at ORNL. The following indicators establish specific long-term goals in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- investigating new regions of nuclear structure, studying interactions in nuclear matter like those occurring in neutron stars, and determining the reactions that created the nuclei of the chemical elements inside stars and supernovae; and
- determining the fundamental properties of neutrinos and fundamental symmetries by using neutrinos from the sun and nuclear reactors and by using radioactive decay measurements.

The Nuclear Theory subprogram will contribute to Strategic Goals 3.1 and 3.2 by providing the theoretical underpinning needed to support the interpretation of a wide range of data obtained from all the other NP subprograms, with the ultimate aim of advancing knowledge and providing insights into the most promising avenues for future research. A major theme of this subprogram is an understanding of the mechanism of quark confinement and de-confinement—while it is expected to be explained by Quantum Chromodynamics (QCD), a quantitative description remains one of this subprogram's great intellectual challenges. New theoretical tools will be developed to describe nuclear many-body phenomena, with important applications to condensed matter and other areas of physics. Understanding what consequences neutrino mass has for nuclear astrophysics and for the current theory of elementary particles and forces is also of prime importance. Computing resources are being developed to tackle challenging calculations of sub-atomic structure, such as those of Lattice Gauge QCD.

The Nuclear Theory subprogram also supports an effort in nuclear data that collects, evaluates and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies. These extensive nuclear databases are a national resource consisting of carefully organized scientific information that has been gathered over 50 years of low-energy nuclear physics research worldwide.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.47.00 Explore Nuclear Matter - from Quarks to Stars			
Nuclear Physics	357,756	454,060	471,319

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 3.1/2.47.00 – Explore Nuclear Matter, from Quarks to the Stars					
Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 11%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 12%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 13%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 6%, on average, of scheduled operating time. [Met Goal]	Average achieved operation time of the scientific user facilities as a percentage of the total scheduled annual operation time will be greater than 80%.	Average achieved operation time of the scientific user facilities as a percentage of the total scheduled annual operation time will be greater than 80%.
					Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects will be within 10%.
Medium Energy Nuclear Physics					
As elements of the electron beam program, (a) completed commissioning of the BLAST detector at MIT/Bates and initiated first measurements, and (b) completed 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) collected first data with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) collected 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. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.83), Hall B (8.06), and Hall C (2.11), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (1.77), Hall B (9.9), and Hall C (1.9), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.2), Hall B (11.6), and Hall C (2.6), respectively, at the Continuous Electron Beam Accelerator Facility.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (4), Hall B (20) and Hall C (5), respectively, at the Continuous Electron Beam Accelerator Facility.
				Weighted average number (within 30% of baseline estimate) of millions of proton collision events sampled by the PHENIX (120,000) and recorded by the STAR (158) detectors, respectively during the polarized proton run at the Relativistic Heavy Ion Collider.	Weighted average number (within 30% of baseline estimate) of millions of proton collision events sampled by the PHENIX (600,000) and recorded by the STAR (40) detectors, respectively during the polarized proton run at the Relativistic Heavy Ion Collider.

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
Heavy Ion Nuclear Physics					
Completed first round of experiments at RHIC at full energy; achieved the full design luminosity (collision rate) of 2 x 10^{26} cm^{-2} s^{-1} for heavy ions. [Met Goal]	Initiated first round of experiments with collisions with other ions to compare to results of gold-gold collisions. [Met Goal]	Weighted average number (within 30% of baseline estimate of millions of events sampled by the PHENIX (900) and recorded by the STAR (40) detectors, respectively, at the Relativistic Heavy Ion Collider. [Met Goal]	No Target. (The Relativistic Heavy Ion Collider did not operate in heavy ion mode during FY 2006)	Weighted average number (within 30% of baseline estimate) of millions of events sampled by PHENIX (30,000) and recorded by the STAR (100) detectors, respectively during the heavy ion run at the Relativistic Heavy Ion Collider.	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (7,500) and recorded by the STAR (60) detectors, respectively during the heavy ion run at the Relativistic Heavy Ion Collider.
Low Energy Nuclear Physics					
		Weighted average number (within 20% of baseline estimate of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (28.1) and Holifield Radioactive Ion Beam (3.76) facilities, respectively. [Met Goal]	Weighted average number (within 20% of baseline estimate of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (24.6) and Holifield Radioactive Ion Beam (7.1) facilities, respectively. [Met Goal]	Weighted average number (within 20% of baseline estimate of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (22) and Holifield Radioactive Ion Beam (1.8) facilities, respectively.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (22) and Holifield Radioactive Ion Beam (2.4) facilities, respectively.

Means and Strategies

The NP program will use various means and strategies to achieve its program goals. However, various external factors may impact the ability to achieve these goals.

NP will support innovative, peer reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, in particular to investigate the fundamental forces that hold the nucleus of the atom together and determine the detailed structure and behavior of atomic nuclei. The program also builds and supports the forefront scientific facilities and instruments necessary to carry out that research. All research projects undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar process for laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) changing mission needs as described by the DOE and SC mission statements and strategic plans; (2) evolving scientific opportunities, which sometimes emerge in a way that revolutionizes disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or subfields, such as those reviews performed by the National Academy of Sciences; (4) unanticipated failures, for example, in critical components of scientific user facilities, that cannot be mitigated in a timely manner; and (5) strategic and programmatic decisions made by other Federal agencies and by international entities.

NP is closely coordinated with the research activities of the NSF. The major scientific facilities required by NSF-supported scientists are usually the DOE facilities. NSF often jointly supports the fabrication of major research equipment at DOE user facilities. DOE and NSF jointly charter the Nuclear Science Advisory Committee (NSAC).

Scientists supported by NP collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the NP national user facilities. The program also supports some collaborative work at foreign accelerator facilities. The program promotes the transfer of the results of its basic research to a broad set of technologies involving advanced materials, national defense, medicine, space science and exploration, advanced computing, and industrial processes. In particular, nuclear reaction data are an important resource for these programs. NP user facilities are utilized by other SC programs, other DOE Offices (e.g., National Nuclear Security Administration and Nuclear Energy), other Federal agencies (e.g., NSF, NASA, and Department of Defense) and industry to carry out their programs.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Periodic assessments and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART)

The Department has implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government’s portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The NP program has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2005 PART assessment, OMB gave the NP program a rating of “Effective”. OMB found the program’s management to be excellent with a relatively transparent budget justification and a fully engaged advisory committee that produces fiscally responsible advice. The assessment found that NP has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, NP grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain these complex scientific measures, SC has developed a website (http://www.sc.doe.gov/measures) that answers questions such as “What does this measure mean?” and “Why is it important?” Roadmaps, developed in consultation with the NSAC are also available on the website. NSAC will review the progress towards achieving the long term Performance Measures every five years. The Annual Performance Targets are tracked through the Department’s Joule system and reported in the Department’s Annual Performance and Accountability Report.

OMB has previously provided NP with three recommendations to further improve performance:

- Respond to the recommendations of recent advisory committee reports, including implementing a budget-constrained and phased plan for the future of its research facilities.
- Engage the National Academies, including experts outside of nuclear physics, to study the scientific capabilities of a proposed rare isotope accelerator in an international context.
- Maximize operational efficiency of major experimental facilities in response to increasing power costs.

In response to the OMB recommendations, NP:

- Continues to engage its advisory committee in a manner that produces responsible strategic advice within realistic budget scenarios. In 2006, DOE and NSF charged NSAC to develop a new long-range plan for nuclear science; a report is expected by the end of 2007. This 2008 budget request is one of many actions that NP is taking to respond to the recommendations of recent NSAC reports.
- Continues to use external expert assessments (Committee of Visitors [COVs]) to review the quality, relevance, and performance of the program's research portfolio and grant management process. The last COV review was held January 9-11, 2007.
- Engaged the National Academies to study the scientific opportunities of a proposed rare isotope beam facility and has encouraged broad representation from the scientific community. The final Academies report will be available in spring 2007 and posted at http://www.sc.doe.gov/np/.
- Continues to maximize the utilization and efficiency of major experimental facilities to ensure that the Nation’s Nuclear Physics program achieves maximum results. In addition to annual science and technology reviews of each of its facilities, NP conducted a focused review on optimizing operational efficiency of its four national user facilities in the summer of 2006.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov website. Information concerning NP PART assessments and current follow up actions can be found by searching on “nuclear physics” at http://www.ExpectMore.gov.

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 benefits, especially to medicine, emerged from these efforts. But today, nuclear science is much more than this. Its reach extends from the quarks and gluons that form the substructure of the once-viewed-as-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; however, the field is driven by the following broad questions as stated by the Nuclear Science Advisory Committee (NSAC) in the *Opportunities in Nuclear Science: A Long-Range Plan for the Next Decade (2002)*.

- *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 and compressed 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 supersymmetry to the Standard Model. Precision nuclear physics experiments 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 the core university and national laboratory programs, and maintaining a strong infrastructure to support nuclear physics research. The R&D Investment Criteria's relevance principles encourage research community investments in making program priorities. The NSAC and Program Advisory Committees (PACs) at our facilities have served the program well in this respect. Quality and performance are assured by peer-review of research projects and facility operations. The performance data obtained in facility and program reviews, as well as Annual Performance Results and Targets, are used in assuring quality and in making funding decisions.

Advisory and Consultative Activities

To ensure that resources are allocated to the most scientifically promising research, the DOE and its national user facilities actively seek external input using a variety of advisory bodies.

The NSAC provides advice to the DOE and the NSF on a continuing basis regarding the direction and management of the national nuclear sciences basic research program. In FY 2007, the DOE Nuclear Physics program will provide about 90% of the federal support for fundamental nuclear physics research in the Nation. The NSF provides most of the remaining support. One of the most important functions of NSAC is the development of long-range plans that express community-wide priorities for the upcoming decade of nuclear physics research. NSAC regularly conducts reviews that evaluate the scientific productivity of and opportunities in major components of the Office's research program and proposed major new initiatives, and provides advice regarding scientific priorities. In 2005 DOE and NSF requested that NSAC and the High Energy Physics Advisory Panel (HEPAP) jointly appoint a Neutrino Science Assessment Group (NuSAG) to assess and make recommendations concerning opportunities in neutrino science. NuSAG has responded with two reports on these opportunities: on experiments to search for neutrino-less double beta decay and hence discover if the neutrino is its own anti-particle, and determine or limit the neutrino mass; and on the measurement of neutrino oscillation mixing parameters utilizing neutrinos produced by reactors and accelerators. NuSAG is continuing to assess the opportunities for long baseline accelerator experiments to probe non-conservation on CP (charge-parity symmetry) in the neutrino sector. The published reports can be found at http://www.sc.doe.gov/np/nsac/nsac.html. In FY 2006, NSAC was presented with charges for a Committee of Visitors (COV) review of the Office of Nuclear Physics, to evaluate the scientific reach and technical options for a rare isotope beam facility, and to develop a new long-range plan. A report on the COV is expected early in 2007, a report on the rare isotope facility is expected in spring 2007, and the report on the long-range plan is expected by the end of 2007.

The National Academy of Sciences (NAS) was charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation rare isotope beam facility. The draft report, *Scientific Opportunities with a Rare Isotope Facility in the United States,* completed in December 2006, addresses the role of a U.S. world-class rare isotope beam facility for the future of U.S. and international nuclear physics.

Facility directors seek advice from PACs to determine the allocation of scarce scientific resources—the available beam time. The committees are comprised of members mostly external to the host laboratory who are appointed by the facility director. PACs review research proposals requesting time at the facilities and technical resources, and provide advice on a proposal's scientific merit, technical feasibility, and personnel requirements. The PAC also provides recommendations for proposals to be approved, conditionally approved, deferred, or rejected.

Facility Science and Technology Reviews

Science and Technology (S&T) Reviews of the NP program's four National User Facilities – RHIC, CEBAF, ATLAS, and HRIBF – are conducted annually with external experts from U.S. and foreign institutions to assess the performance and scientific productivity of the facilities. The results of the review are compared to goals defined in approved Laboratory Performance Evaluation Management Plans, and the NP program's assessment of the laboratory performance is documented in annual

Laboratory appraisals. During the summer 2006, NP conducted a review focused on optimizing the operating efficiency of NP accelerator facilities.

In addition, the NP program also reviews, with international experts, proposed and ongoing instrumentation projects to assess project plans and performance. These reviews focus on scientific merit, technical status and feasibility, cost and schedule, and effectiveness of management organizations. Such reviews are conducted on an annual basis and provide important input in establishing cost and schedule profiles necessary for budget formulation and execution, and assessing project performance.

Program Reviews

Quality and productivity of university grants are peer reviewed on a three-year basis and laboratory groups performing research are peer reviewed on a four-year basis. NSAC periodically 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. The most recent reviews were of the Theory subprogram in 2004, the Heavy Ion subprogram in 2005, and the Medium Energy subprogram in 2006. The Low Energy subprogram will be reviewed in 2007.

Planning and Priority Setting

The strategic plan for NP is set forth in the DOE and SC Strategic Plans. NP develops its strategic plan with input from the scientific community. 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 five to six 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. The plan provides guidance and recommends priorities for new construction projects. For example, the 12 GeV CEBAF Upgrade was identified as a high priority in the 2002 NSAC Long-Range Plan, and was incorporated into NP's strategic plan. The Upgrade was identified as a near-term priority in the SC future facilities outlook, (Facilities for the Future of Science: A Twenty-Year Outlook) and is included in the FY 2008 budget with a request for continued support to complete Project Engineering and Design (PED) activities.

The DOE and NSF have charged NSAC to develop a new long-range plan for nuclear science, with the input of the research community, to provide guidance to the agencies into the next decade. This plan will be available by the end of 2007.

Guidance from the NSAC long-range plans are augmented by NSAC reviews of subfields. Priorities identified in NSAC reviews of the Medium Energy and Low Energy subprograms were important input for the programmatic decisions to terminate user facilities operations of the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL) in FY 2004 and of the Bates Linear Accelerator Center at the Massachusetts Institute of Technology in FY 2005. NSAC guidance on scientific opportunities and priorities, provided in reviews of neutron science, the Nuclear Theory and Heavy Ion subprograms, and the FY 2006 review of the Medium Energy subprogram is reflected in the programmatic decisions in the FY 2007 and FY 2008 budget requests. NSAC's guidance from its review of the entire program in the context of constrained funding, transmitted in a June 2005 report, is taken into account for the FY 2008 budget. These decisions have been made to maximize the scientific impact, productivity, quality and cost-effectiveness of the program within the resources available.

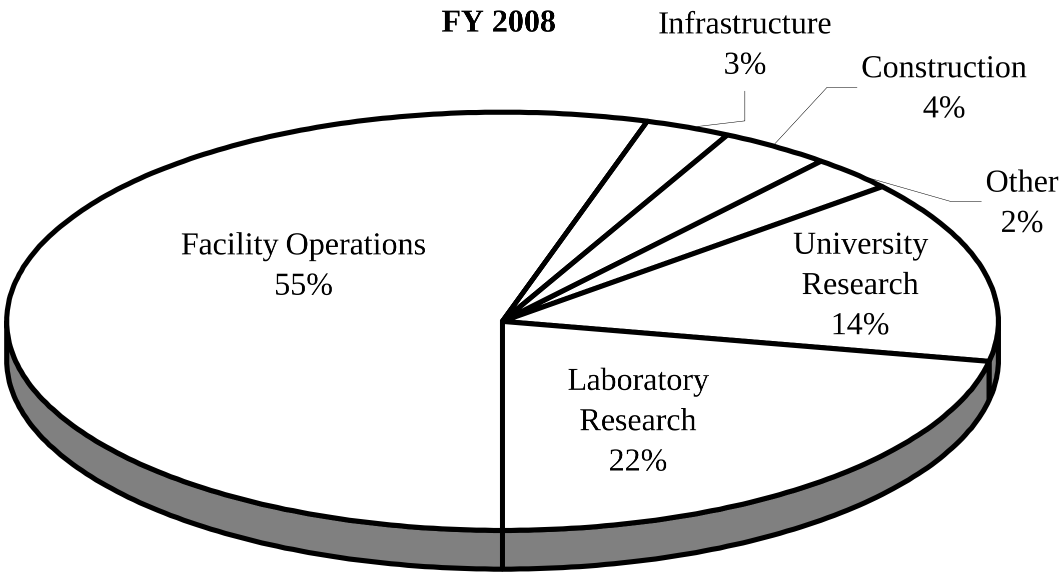
In order to better coordinate interagency activities, NP continues to participate in the Interagency Working Group (IWG) that developed the National Science and Technology Council (NSTC) Report: A 21st Century Frontier for Discovery: The Physics of the Universe—A Strategic Plan for Federal

Research at the Intersection of Physics and Astronomy. NP is playing a leading role in two of the major scientific thrusts identified in this report: Origin of Heavy Elements and High Energy Density Physics. Funding is continued in FY 2008 to partially support the thrust on the Origin of the Heavy Elements at existing low energy facilities and to support aspects of High Energy Density Physics with heavy ions at RHIC and participation in the heavy ion program at the LHC, all in the context of the Nuclear Physics mission.

How We Spend Our Budget

The FY 2008 budget request is focused on optimizing, within the resources available, the scientific productivity of the program by ensuring a proper balance of research workforce, facility operations, and investments in needed tools and capabilities. 36% of the funding is provided for research personnel to utilize the program's user facilities, complete important experiments and to fabricate experimental instrumentation. 55% of the funding is provided for operations of the program accelerator facilities. 7% is provided for infrastructure and for construction projects that are needed to extract the science and improve efficiencies in the outyears and 2% for other activities that include Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs.

Nuclear Physics Budget Allocation
FY 2008



Research

About 36% of the program's funding is provided to scientists at universities and laboratories to conceive and carry out the research. The NP program involves over 1,900 researchers and students at over 100 U.S. academic, federal and private sector institutions. The program funds research activities at approximately 85 academic institutions located in 34 states and the District of Columbia and at 7 DOE laboratories in 6 states. Funding is increased by 3.9% compared to FY 2007. 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. In FY 2007, the DOE Nuclear Physics program supports 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 at university Centers of Excellence that include laboratories with local accelerators (Texas A&M Cyclotron Laboratory, Triangle Universities Nuclear Laboratory (TUNL) at Duke University, and Yale University), the Center for Experimental Nuclear and Particle Astrophysics (CENPA) at the University of Washington, the Research and Engineering Center at the Massachusetts Institute for Technology, and the Institute for Nuclear Theory at the University of Washington. In recent years about 80 Ph.D. degrees have been granted annually to students for research supported by the program. Approximately one-half of those who received nuclear science Ph.D.'s pursue careers outside universities or national laboratories in such diverse areas as nuclear medicine, medical physics, space exploration, and national security.

  The university grants program is proposal driven. 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/grants/). 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, Thomas 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. Collaborations of laboratory researchers with academic users of the facilities are important for developing and maintaining the large experimental detectors and computing facilities for data analysis. Nuclear Physics program funding plays an important role in supporting basic research that can improve 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. Performance of the laboratory groups is reviewed approximately every four years 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. In FY 2006, the research of national laboratory Medium Energy groups was reviewed.

Nuclear physics has made important contributions to our knowledge about the universe in which we live 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.

Significant Program Shifts

The FY 2008 budget request continues overall operations of the four National User Facilities and research efforts at universities and laboratories at approximately FY 2007 levels. At this level, the NP-supported user facilities allow researchers to make effective progress towards the program's scientific goals and milestones, and investments are made in new capabilities to address compelling scientific opportunities and maintain U.S. competitiveness in global Nuclear Physics efforts.

New instrumentation initiatives include U.S. contributions to the Italian Cryogenic Underground Observatory for Rare Events (CUORE) project, a neutrino-less double beta decay experiment that will measure the absolute mass of the neutrino, and upgrades to the RHIC PHENIX experiment to install new detectors important for both the heavy ion and spin programs.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all SC 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 of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians.

In FY 2006 applications for new SciDAC projects were evaluated and the Nuclear Physics program is currently funding grants in the areas of theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (Computational Astrophysics Consortium), grid technology (Open Science Grid), and low energy nuclear structure and reactions (Building a Universal Nuclear Energy Density Functional) that support the scientific goals of the Nuclear Physics subprograms. The National Computational Infrastructure for Lattice Gauge Theory has an aim to make precision numerical calculations of QCD in order to determine the structure and interactions of hadrons and the properties of nuclear matter under extreme conditions. This activity provides results coordinated with a similar activity by the High Energy Physics (HEP) program. The principal goal of the Computational Astrophysics Consortium is to understand in detail the explosion mechanism of Type 1 supernovae that are used as “standard candles” to determine cosmological distances in the universe and to highlight nuclear uncertainties in understanding of nucleosynthesis in stars and supernovae; uncertainties that could guide the program of new rare isotope beam experimental facilities. The Open Science Grid project is allowing nuclear physics experiments to continue the task of replicating and transmitting across the globe thousands of files at high speeds with rates in excess of 3-4 terabytes/week. The Universal Nuclear Energy Density Functional has as its aim the creation of a unified theory of nuclear structure and reactions grounded in fundamental theory by developing a Universal Nuclear Energy Density Functional (UNEDF) to predict nuclear properties and reactions with unprecedented accuracy and clearly-defined uncertainties. This new capability will address old issues of nuclear science but is primarily aimed at the theoretical calculation of the structure and reactions of rare nuclei that will become accessible at new experimental facilities and are important to explore new phenomena in nuclei, and to calculate reactions crucial to understanding the origin of the elements heavier than iron and applied nuclear areas.

Scientific Facilities Utilization

NP’s four National User Facilities provide research time for scientists in universities and other Federal laboratories in FY 2008.

- The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL);
- The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF);
- The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL); and

- The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL).

These facilities provide beams for research for a user community of about 3,000 U.S. and international scientists. The FY 2008 budget request will support operations at these facilities that will provide an estimated 19,035 hours of beam time for research, similar to the anticipated beam hours in FY 2007.

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.

	FY 2006	FY 2007	FY 2008
Number of Facilities	4	4	4
Optimal Hours	22,675	22,675	22,400
Planned Operating Hours	11,435	19,015	19,035
Achieved Operating Hours	16,757	N/A	N/A
Unscheduled Downtime—Major user facilities	6.4%	N/A	N/A
Number of Users[a]	2,670	1,990	3,035

Achieved operating hours in FY 2006 do not include RHIC/BNL running which used non-DOE funds for operating in FY 2006. The achieved operating hours exceeded planned operating hours in FY 2006 because ATLAS/ANL deferred a planned maintenance shutdown period into FY 2007 to permit additional running (which will impact FY 2007 operations), TJNAF focused on lower energy running which is less costly, and HRIBF focused on the less costly stable beam running instead of radioactive beam running.

Construction and Infrastructure

Funding is provided in the FY 2008 request to complete construction of the RHIC Electron Beam Ion Source (EBIS), a joint DOE/NASA project. Critical Decision-2 (CD-2), Approve Performance Baseline, and CD-3, Approve Start of Construction, for the EBIS project were approved in FY 2006. The EBIS will replace the aging Tandems as a new pre-injector for RHIC, offering increased reliability and efficiency, and reduced operating costs.

Project engineering and design funds are provided in FY 2008 for the 12 GeV CEBAF Upgrade at TJNAF to complete design activities; funding is also provided to complete the R&D portion of the project. The Upgrade project will enable scientists to address the mechanism that "confines" quarks together with a scientific portfolio that cannot be addressed at any other machine in the world. The SC Office of Project Assessment conducted a Project Status Review in 2006 of the 12 GeV CEBAF Upgrade project to evaluate the R&D progress and project performance. Critical Decision-1 (CD-1), Approve Alternative Selection and Cost Range, was approved in FY 2006.

The Nuclear Physics program provides funding for general plant projects (GPP) at BNL and TJNAF and general purpose equipment (GPE) at BNL to address laboratory infrastructure needs. Facility capital equipment and accelerator improvement project support is provided to the four NP National User Facilities (RHIC, TJNAF, HRIBF, and ATLAS) to provide modest new capabilities and address facility infrastructure needs. 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.

---

[a] The counting of users at the NP facilities has been improved to ensure consistent counting methodology from one facility to the next and to remove possible double counting. The more accurate count is reflected in the FY 2008 column, which is similar to projections for 2007.

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 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 approximately three new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty and future leaders of the field.

About 830 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2006 were involved in a large variety of experimental and theoretical research projects. Over one fifth 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.

Details of the DOE Nuclear Physics workforce are given below. Almost all university grants are awarded with project periods of three years.

	FY 2006 actual	FY 2007 estimate	FY 2008 estimate
# University Grants	180	190	190
Average size (excluding CE)	$305,000	$340,000	$355,000
# Laboratory Groups	27	27	27
# Permanent Ph.D.'s	590	650	640
# Postdoctoral Associates	344	380	370
# Graduate Students	486	500	490
# Ph.D.'s awarded	92	80	80

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007, the EIR business line is financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Medium Energy Nuclear Physics			
Research			
University Research	15,748	18,103	18,646
National Laboratory Research	15,162	16,983	17,567
Other Research[a]	688	5,684	5,917
Total, Research	31,598	40,770	42,130
Operations			
TJNAF Operations	69,063	80,011	79,249
Bates Facility	2,500	2,000	2,000
Total, Operations	71,563	82,011	81,249
Total, Medium Energy Nuclear Physics	103,161	122,781	123,379

Description

The Medium Energy Nuclear Physics subprogram supports fundamental research directed primarily at answering the first of the five central 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 Chromodynamics (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.

Benefits

The matter that makes up our world is the result of a unique property of the strong interaction called “confinement” that binds quarks and gluons together to form nucleons, the building blocks of atomic nuclei. Confinement prevents quarks or gluons from ever existing in isolation; they always bind in complex structures to form subatomic particles. Characterizing confinement and how it gives these subatomic particles, specifically protons and neutrons, their particular properties is the focus of the Medium Energy subprogram. By providing precision experimental information concerning the quarks and gluons that form the protons and neutrons, this subprogram, in coordination with the Theory subprogram, seeks to provide a quantitative description of these particles in terms of the fundamental theory of the strong interaction, QCD. This work provides a basis for our description of matter in terms of its fundamental constituents and strengthens scientists’ ability to explore how matter will behave under conditions that cannot be duplicated by humans.

---

[a] In FY 2006, $3,450,000 has been transferred to the SBIR program and $994,000 has been transferred to the STTR program. This activity also includes $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007 and $3,934,000 for SBIR and $1,224,000 for STTR in FY 2008.

The laws of quantum physics state that the angular momenta of quarks and gluons should add up to the proton's known spin (intrinsic angular momentum), but experimental data hint that quarks by themselves account for about 20% of the proton's spin. During the 2006 RHIC running, polarized protons were accelerated to the highest energies ever recorded—250 billion electron volts (GeV) or two-and-a-half times the typical proton collision energies studied at RHIC. From the preceding proton runs at RHIC, researchers got their first exciting glimpses of results that depend on the contribution of gluons to the proton's spin. The latest run, the first in series of planned runs for amassing high-statistics, will provide accurate results on the gluon contribution and set the stage for colliding protons at much higher energies where the spin-flavor quark structure of nucleon could be measured directly using maximal parity violation for production of W bosons. To accomplish these tasks, the Medium Energy subprogram operates the CEBAF at the Thomas Jefferson National Accelerator Facility (TJNAF), supports research at the RHIC at Brookhaven National Laboratory (BNL), and supports university researchers to carry out the experiments at these facilities and elsewhere. These research activities contribute to the training of the next generation of scientists and engineers that will contribute to the Department's energy and national security missions.

Supporting Information

To achieve an experimental description of the nucleon's substructure, the Medium Energy subprogram supports different approaches that focus on: (1) determining the distribution of up, down, and strange quarks in the nucleons, the role of the "sea" of virtual quarks and gluons (which makes a significant contribution to the properties of protons and neutrons) and the dynamic degrees of freedom of the quarks by measuring the excited states of hadrons (any composite particle made of quarks, such as nucleons); and (2) determining the effects of the quark and gluon spins within the nucleon and the properties of simple, few-nucleon systems, with the aim of describing them in terms of their fundamental components.

Most of this work has been done at the subprogram's primary research facility, TJNAF, as well as a major research effort at RHIC. Individual experiments are supported at the High Intensity Gamma Source (HIGS) at Triangle University Nuclear Laboratory, Fermilab, and facilities in Europe. All these facilities produce beams of sufficient energy (small enough wavelength) to probe at a distance scale within the size of a nucleon. The operation of the National User Facility, CEBAF at TJNAF, annually serves a nationwide community of about 800 DOE and National Science Foundation (NSF) supported scientists and students from over 80 U.S. institutions and about 400 scientists from 19 foreign countries. The NSF and foreign collaborators have made significant investments in experimental equipment. Allocation of beam time at TJNAF has been based on guidance from a Program Advisory Committee that reviews and evaluates proposed experiments regarding their merit and scientific priority.

FY 2006 Accomplishments

Scientists supported by this subprogram have made important discoveries in the past decade with advances in both theory and experiments that spurred interest in quantitatively understanding nucleons in terms of the quarks and gluons of QCD. The NSAC Long-Range Plan summarized important accomplishments of the field up to 2002; since then accomplishments are summarized yearly in the budget submission. Recent Medium Energy subprogram developments include:

- The MiniBooNE neutrino oscillation experiment has completed its neutrino data taking after collecting over 7,000,000 neutrino events, achieving its planned goal. The experiment is now taking data with antineutrinos. Analysis of the neutrino data is in its final phase; these results should resolve the question of whether there is an additional type of neutrino (beyond the three known neutrinos) that is suggested in the results of a previous experiment.

- Recent results obtained at CEBAF in Deeply Virtual Compton Scattering experiments demonstrate the feasibility of the technique for determining the General Parton Distributions (GPDs). GPDs provide the opportunity to produce for the first time 3D images of the internal structure of the nucleon and will be a major component of the planned 12 GeV CEBAF Upgrade scientific program.
- Results from CEBAF have significantly improved our knowledge of the role the strange quark plays in the charge and current distributions of the proton and of the charge distribution of the neutron. These results constitute a major milestone in establishing the fundamental properties of the nucleon.
- Measurements with polarized protons at RHIC indicate that the contribution of the gluons to the proton's spin is small. The 2006 spin data set will allow studies of the gluon polarization with greater sensitivity and may provide first measurements on gluon polarization using direct photons. Measurements indicate that the quarks that form the proton contribute only about 20% to the proton's spin.

FY 2006 Facility and Technical Accomplishments

- The successful implementation and operation of a state-of-the-art Time Project Chamber (TPC) together with frozen spin hydrogen and deuterium "ice" targets represent a significant technical achievement and allowed for the successful completion of the Laser Electron Gamma Source (LEGS) experiment at Brookhaven National Laboratory in 2006. The LEGS measurements will provide unique sensitive tests of models describing the internal structure of protons and neutrons, particularly associated with their spin.
- The first demonstration in the world of atom trapping of radium was demonstrated at the Argonne National Laboratory. This technique opens the door to an electric dipole moment experiment using nuclei that could shed light on the matter over antimatter excess in the universe.
- TJNAF is a world leader in superconducting radiofrequency (SRF) technology. Several technical accomplishments in FY 2006 were realized including: a successful demonstration of a prototype superconducting accelerating cavity for use in next generation high power Free Electron Lasers to produce higher power (by a factor of 10-100) infrared light; modification of TJNAF SRF facilities to allow testing and developing of superconducting cavities for a possible International Linear Collider (ILC) with an electro-polished mirror-like inside surface (in collaboration with High Energy Physics); and development of a new manufacturing method of using high-purity niobium straight from the cast billet at the manufacturer to make high performing accelerating cavities, a method with potential cost savings for future accelerator projects.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**31,598**	**40,770**	**42,130**
▪ **University Research**	**15,748**	**18,103**	**18,646**

These activities comprise a broad program of research, and include support of about 160 scientists and 125 graduate students at 36 universities in 19 states and the District of Columbia. The research efforts utilize not only the accelerator facilities supported under the Medium Energy subprogram, but also other U.S. and foreign accelerator laboratories.

Support is provided for university researchers and groups to effectively carry out the CEBAF and RHIC research programs, complete Bates data analysis and maintain staff at the MIT Research and Engineering (R&E) Center. Of this amount, $2,000,000 supports the R&E Center that is an integral component of MIT's medium energy research effort and utilizes the infrastructure remaining at the MIT/Bates facility to participate in fabrication of instrumentation relevant to the NP program's mission. Efforts at TJNAF are largely focused on the study of nucleon structure and its internal dynamics. In FY 2008, this includes research effort for the Q_{weak} experiment (an NSF/DOE effort with international contributions); a precision determination of the weak mixing angle as a constraint on new physics beyond the Standard Model; mapping out of the magnetic form factor of the deuteron to high momentum transfer; and studying quark-quark spin correlations by measuring polarized quark structure functions. Efforts at RHIC will focus on studies to determine the gluon contribution to the spin of the proton.

	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**15,162**	**16,983**	**17,567**

Support for experimental groups at TJNAF maintains CEBAF efforts at the level needed to effectively carry out the research program at the facility. Support for research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories not associated with TJNAF is at a level that will allow these groups to achieve their planned NP goals.

	FY 2006	FY 2007	FY 2008
• **TJNAF Research**	**5,671**	**6,163**	**6,362**

Scientists at TJNAF, with support of the user community, assembled the large and complex experimental detectors for Halls A, B, and C. TJNAF scientists provide necessary experimental support and operation of the detectors for safe and effective utilization by the user community. TJNAF scientists play a lead role in the laboratory's research program and their level of effort is maintained in FY 2008 relative to FY 2007. Due to the improvement of data acquisition infrastructure in the three halls, the data taking capabilities of the experiments have been improved.

	FY 2006	FY 2007	FY 2008
• **Other National Laboratory Research**	**9,491**	**10,820**	**11,205**

Support for research activities at accelerator and non-accelerator facilities maintains a constant level of effort relative to FY 2007, with resources directed towards the highest priority activities that include those described below:

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		

- Argonne National Laboratory scientists will continue their research program at TJNAF. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. ANL scientists have also made important advances in a new laser atom-trapping technique, Atom Trap Trace Analysis (ATTA), which will be used in measurements of rare isotopes for precision studies of nuclear structure and a search for an atomic electric dipole moment. ATTA provided the first demonstration in the world of atom trapping of radium in FY 2006. This result opens the door to an electric dipole moment experiment using nuclei that could shed light on the matter over antimatter excess in the universe.
- Support will be provided to the RHIC spin physics Medium Energy Research groups at BNL and Los Alamos National Laboratory (LANL). Both of these groups have important roles and responsibilities in the RHIC spin physics program.
- The LEGS experiment at BNL was completed in 2006. The FY 2008 request provides reduced support to complete the analysis of data.
- At LANL, scientists and collaborators are participating in the MiniBooNE neutrino oscillation experiment at Fermilab that hopes to determine whether a new type of neutrino exists. Support was provided in FY 2007 to complete this analysis. Reduced support in FY 2008 is provided to transition the group to other high-priority efforts or continue on this topic, dependent on the MiniBooNE result.

	FY 2006	FY 2007	FY 2008
▪ **Other Research**	**688**	**5,684**	**5,917**

In FY 2006, $3,450,000 has been transferred to the Small Business Innovation Research (SBIR) program and $994,000 has been transferred to the Small Business Technology Transfer (STTR) program. This activity includes $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007 and $3,934,000 for SBIR and $1,224,000 for STTR in FY 2008 as well as other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2006	FY 2007	FY 2008
Operations	**71,563**	**82,011**	**81,249**
▪ **TJNAF Operations**	**69,063**	**80,011**	**79,249**

Funding supports CEBAF operations and Experimental Support for an approximate 34-week, 3-Hall operations schedule.

	FY 2006	FY 2007	FY 2008
• **TJNAF Accelerator Operations**	**46,930**	**53,711**	**52,202**

CEBAF operations are supported for a 34 week (4,705 hour) running schedule, a 6% decrease from estimated running in FY 2007, as funds are redirected towards the 12 GeV CEBAF Upgrade. At this level of funding the accelerator provides beams simultaneously to all three experimental halls. In FY 2008, support ($2,030,000) is directed at continuing necessary accelerator improvement projects (AIP) and General Plant Project (GPP) infrastructure improvements are maintained at levels comparable to FY 2007. Support ($1,630,000) is also provided to maintain efforts in developing advances in superconducting radiofrequency technology.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

	FY 2006	FY 2007	FY 2008
CEBAF hours of operation with beam	5,646	4,985	4,705

CEBAF actual hours of operations in FY 2006 exceeded planned operations of 3,405 hours because CEBAF was operated a large fraction of the year at a low energy, which is less expensive than higher energy running, as well as running fewer experimental halls simultaneously. Operations savings were also realized through innovative cost saving techniques in cryogenics.

Funding of $1,000,000 is provided for R&D activities for the upgrade of CEBAF to 12 GeV. The upgrade is recommended as one of the highest priorities for Nuclear Physics in the 2002 NSAC Long-Range Plan for Nuclear Science, was identified as a near-term priority in the SC 20-Year Facilities Outlook, and received Alternate Selection and Cost Range (CD-1) approval by the Department of Energy in February 2006. An SC Office of Project Assessment Project Status Review of the project assessed the R&D plans and project performance, and results from the review are incorporated into this budget request. Project Engineering and Design funding is requested under the Construction section of this budget.

	FY 2006	FY 2007	FY 2008
• **TJNAF Experimental Support**	**22,133**	**26,300**	**27,047**

The FY 2008 request supports Experimental Support efforts at the level needed for a 34-week, 3-Hall operations schedule. Support is provided for the scientific and technical staff, materials, and services needed to support three hall operations and to integrate rapid assembly, modification, and disassembly of large and complex experiments for optimization of schedules. This includes the delivery or dismantling of cryogenic systems, electricity, water for cooling, radiation shielding, and special equipment for specific experiments.

FY 2008 funds for capital equipment ($4,950,000) are used for assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, and C; spectrometer systems; the completion of an upgrade of the data reduction system to handle massive amounts of raw data; and the continuation of the fabrication of second generation experiments. The Q_{weak} detector system is being fabricated to perform a precision measurement of the weak charge of the proton.

	FY 2006	FY 2007	FY 2008
▪ **Bates Facility**	**2,500**	**2,000**	**2,000**

Operation of the MIT/Bates Linear Accelerator Center was phased out and pre-D&D activities were started in FY 2005. Discussions with MIT regarding disposal of property and the final state of the site have been completed. Funds in the amount of $2,000,000 are provided as part of the agreement which turns ownership of the facility over to MIT in exchange for MIT assuming responsibility for all future D&D activities and liability for the facility.

	FY 2006	FY 2007	FY 2008
Total, Medium Energy Nuclear Physics	**103,161**	**122,781**	**123,379**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ **University Research**	
Funding provides support to maintain core university research at near constant effort levels compared to FY 2007.	+543
▪ **National Laboratory Research**	
Funding provides support to maintain laboratory research efforts generally at FY 2007 levels.	+584
▪ **Other Research**	
Increase reflects required SBIR/STTR and other obligations.	+233
Total, Research	**+1,360**
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
FY 2008 funding decreases almost entirely as a result of reduced R&D for the 12 GeV CEBAF Upgrade according to the planned profile as the project moves into final design. Operating hours are reduced by 6% (-280 hours).	-1,509
• **TJNAF Experimental Support**	
The FY 2008 funding request provides a constant level of effort for CEBAF experimental support activities that will support the facility running schedule.	+747
Total, Operations	**-762**
Total Funding Change, Medium Energy Nuclear Physics	**+598**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Heavy Ion Nuclear Physics			
Research			
University Research	11,868	14,013	14,275
National Laboratory Research	19,059	23,326	24,944
Other Research[a]	—	5,014	5,181
Total, Research	30,927	42,353	44,400
Operations			
RHIC Operations	116,447	143,327	146,547
Other Operations	9,283	11,832	12,241
Total, Operations	125,730	155,159	158,788
Total, Heavy Ion Nuclear Physics	156,657	197,512	203,188

Description

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

> *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. However, at extremely high temperatures, 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 extremely small and brief samples of this 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.

Benefits

The Heavy Ion Nuclear Physics subprogram supports the mission of the Nuclear Physics program by engaging in fundamental experimental research directed at acquiring new knowledge on the novel properties and the phases of hot, high energy density nuclear matter such as existed in the early universe; by supporting research and development of the next generation particle detectors, advanced accelerator technologies, state-of-the-art electronics, software and computing; and by training scientists needed by the Nation's diverse high-skills industries and academic institutions.

---

[a] In FY 2006, $3,573,000 has been transferred to the SBIR program. This activity includes $4,918,000 for SBIR in FY 2007 and $5,117,000 for SBIR in FY 2008.

Supporting Information

Historically, the first major milestone in establishing the idea for the formation of heated nuclear matter was marked in 1984 when scientists working at the LBNL Bevalac accelerator found the first direct evidence that nuclear matter can be compressed to high temperature and density using accelerated beams. This observation led to the studies of hot and extremely dense hadronic matter created in heavy ion collisions with gold beams at the BNL Alternating Gradient Synchrotron (AGS) in 1992 and at the CERN Super Proton Synchrotron (SPS) in 1994. These tiny "fireballs" equilibrated rapidly, suggesting that the right conditions should exist at even higher beam energies to create a new phase of metamorphosed matter called the quark-gluon plasma (QGP)—named in the popular press as the mini "Big Bang," since this primordial form of matter is thought to have existed shortly after the birth of the universe.

A new program of research on hot nuclear matter began at the Relativistic Heavy Ion Collider (RHIC) at BNL in 2000 when the first collisions of counter-circulating gold nuclei were observed at beam energies ten times higher than those available at any other facility in the world. While the RHIC facility puts heavy ion research at the highest energy frontier, it is also the only facility in the world that provides collisions of polarized protons with polarized protons. This unique capability will allow information to be obtained on the intrinsic arrangement of gluons that bind quarks into a nucleon (a proton or a neutron). At the opposite end of the temperature scale, limited studies into the conditions for inducing the liquid-to-gas phase transition in nuclear matter are underway at the National Superconducting Cyclotron Laboratory (NSF funded) at Michigan State University, at Texas A&M University, and at foreign laboratories.

The construction of RHIC was completed in August 1999 and RHIC has operated over six highly successful running periods: Run 1 in FY 2000 with gold beams; Run 2, in FY 2001-2002, with gold beams and commissioning of polarized protons; Run 3 in FY 2003, with deuteron-gold collisions and the first physics results with polarized proton collisions; Run 4 in FY 2004 with high luminosity gold beams and polarized protons; Run 5 in FY 2005 with high luminosity copper beams and polarized protons; and Run 6 in FY 2006 devoted to high statistics polarized proton operations. This facility is utilized by about 1,200 DOE, NSF, and foreign agency supported researchers.

The NSAC Subcommittee Review of Heavy Ion Nuclear Physics in 2004 found the long-term plans for expanding the scientific reach of the U.S. nuclear physics program in QCD physics were well formulated and had excellent prospects for new discoveries and for developing a deeper understanding of the properties of nuclear matter and of the origins of the universe.

The LHC, nearing completion at CERN, offers opportunities for new discoveries in relativistic heavy ion physics, driven by a 30 fold increase in center-of-mass energy, which generates different initial conditions and a larger kinematic reach for hard probes. A very modest U.S. research and detector development effort at the LHC is supported that will build upon the discoveries made at RHIC. The LHC is expected to commence heavy ion operations in the 2008 time frame.

FY 2006 Accomplishments

The fifth running period in FY 2005 successfully accelerated and delivered the first high intensity beams of copper nuclei—a landmark accomplishment in itself—that provides physicists greater insights into the remarkable properties of the QGP and the Color Glass Condensate (CGC). In FY 2006, the entire sixth running period (Run-6) was dedicated to understanding the proton "spin crisis", as researchers collided beams of polarized protons at various collision energies.

- RHIC experiments have published results in a special issue of the scientific journal "Nuclear Physics A" that summarize the accomplishments of the first three years of RHIC operation with the description that the medium created at RHIC – which corresponds to the state of the Universe at an early stage of the "Big Bang"—is a perfect and strongly interacting fluid (the sQGP) and not a gas as originally thought. This discovery made the American Institute of Physics list as the top physics story for 2005.
- Preliminary direct photon measurements in gold-on-gold (Au+Au) collisions hint that the spectrum could be the thermal radiation emanating from the sQGP. Researchers believe this thermal effect should be absent in proton-on-proton (p+p) and deuterium-on-gold (d+Au) collisions, as they lack the conditions needed to create the sQGP.
- First indirect hints of the suppression of charm mesons in Au+Au collisions have been observed, indicating that the heavy charm quark loses energy in the sQGP medium. The large suppression, approximately equal to that of the pions, contradicts theoretical expectations and indicates the sQGP medium is so dense that the heavy quarks are not detected in the expected abundances, stimulating further theoretical developments of the "perfect fluid".
- Measurements of anisotropic flow of charm mesons via non-photonic electrons have been made. The results suggest that flow is partonic, that is, arising from early interactions among quarks and gluons.
- First measurements of J/Psi (J/Ψ) particle production from d+Au, copper-on-copper (Cu+Cu) and Au+Au collisions are intriguingly similar to the earlier CERN results. Surprisingly, theoretical models that were successful in describing CERN data fail to describe data at RHIC – a challenge for physicist's conception of the sQGP.

FY 2006 Facility and Technical Accomplishments

- RHIC successfully operated with proton beams. A new beam polarization record of 65% at 100 GeV beam energy was achieved at a luminosity about three times higher than during last year's run. This record breaking performance has exceeded all expectations and accordingly provided significantly more data for the experiments, as well as additional runs at lower beam energies.
- A short test run at full proton beam energy of 250 GeV was successfully concluded. This achievement represents an important technical milestone for the RHIC proton spin program.
- The first successful test of stochastic cooling of high energy, bunched beams was accomplished in one ring at RHIC by using state-of-the-art fiber optic technology for signal processing and powerful narrow-band beam kickers.
- Electron cooling is required for delivering significantly higher beam luminosity. Design of a superconducting high-current cavity capable of record currents of a few amperes for continuous wave (CW) operation was completed in FY 2006. A diamond amplified photocathode has demonstrated a gain of over 50 in emission mode. The accelerator cavity, electron gun, and photocathode are important enabling technologies not only for electron cooling of RHIC, but also for other applications, such as defending Navy ships with a high-power Free Electron Laser, new synchrotron light sources, industrial use of coherent light, and medical imaging.
- The PHENIX experiment built and tested a full scale prototype of the Hadron Blind Detector (HBD) at BNL in collaboration with the Israeli Weizmann Institute. The HBD will measure low mass e+ e- pairs, including the continuum and resonances that auspicate possible mass shifts and other unexplained phenomena observed at CERN. A new detector, the Muon Piston Calorimeter (MPC), was built, tested, calibrated, and installed in PHENIX in FY 2006. The purpose of the MPC is to

measure the production of neutral pions and gamma radiation in p+p and d+A reactions in the forward direction and their spin asymmetries in polarized p+p collisions.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**30,927**	**42,353**	**44,400**
▪ **University Research**	**11,868**	**14,013**	**14,275**

Support is provided for the research of about 120 scientists and 90 graduate students at 27 universities in 21 states. Funding provides support to maintain university research at near constant levels for research efforts at RHIC and the continuation of a modest program at the LHC.

Researchers using relativistic heavy ion beams are focused on the study of the properties of hot, dense nuclear matter created at experiments at RHIC, next generation instrumentation for RHIC, and planning of new experiments at the LHC. The university groups provide scientific personnel and graduate students needed for running the RHIC experiments, data analysis and publishing RHIC results, and designing and fabricating the RHIC and LHC heavy ion detector upgrades.

Support is provided for a small-scale research program conducted at the NSF-supported National Superconducting Cyclotron Laboratory at Michigan State University, at the DOE-supported Texas A&M University, and at facilities in France and Italy.

▪ **National Laboratory Research**	**19,059**	**23,326**	**24,944**

Support is provided for scientists at five national laboratories (BNL, LBNL, LANL, ORNL, and Lawrence Livermore National Laboratory (LLNL). These scientists provide essential personnel for designing, fabricating, and operating the RHIC detectors; analyzing RHIC data and publishing scientific results; conducting R&D of innovative detector designs, integrating electronics designs for high bandwidth data acquisition systems, and software technologies; designing, fabricating, and operating LHC detectors; and planning for future experiments. Also, BNL and LBNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development.

• **BNL RHIC Research**	**8,959**	**11,230**	**11,444**

BNL scientists play a major role in planning and carrying out research using the data acquired from the detectors at RHIC as well as having major responsibilities for maintaining, improving and developing the computing infrastructure for use by the scientific community. The FY 2008 budget request allows BNL scientists to continue to provide adequate maintenance and infrastructure support of the experiments and effectively utilize the beam time for research and to train young scientists. The PHENIX Silicon Vertex Tracker (VTX) MIE (estimated TEC $4,600,000), a joint project with the Japanese, is continued in FY 2008. The PHENIX VTX is a barrel of silicon pixel and strip detectors that will provide precision measurement of heavy quark production to study the thermalization process in the heavy ion collisions. The STAR Time of Flight (TOF) detector requested final funding in FY 2007 and project activities continue in FY 2008 for a FY 2009 completion. Capital equipment funds support the initiation of two MIE's in FY 2008, the PHENIX Nose Cone Calorimeter (NCC) and the PHENIX Forward Vertex Detector (FVTX) . These new detectors are important for both the heavy ion and spin programs. The NCC (estimated TEC $4,700,000) is a fine grained silicon-tungsten sampling calorimeter

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

that will measure the production of heavy quarks in order to characterize the new states of matter created at RHIC. The FVTX (estimated TEC $4,950,000) will provide vertex tracking capabilities to PHENIX and adds two silicon endcaps to the ongoing PHENIX VTX upgrade MIE, to be initiated in FY 2007. Studies directed at developing the scientific case for a potential electron-heavy ion collider facility are supported.

• **Other National Laboratory Research**	**10,100**	**12,096**	**13,500**

Researchers at LANL, LBNL, LLNL, and ORNL provide unique expertise and facilities for detector upgrades and analyses of data. For example, at LBNL, a large scale computational system, Parallel Distributed Systems Facility (PDSF), is a major resource used for the analysis of RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), and at LLNL substantial computing resources are made available for the PHENIX data analysis. Research efforts are maintained at a near constant level of effort as compared to FY 2007. Capital Equipment funding is provided to continue U.S. participation in the heavy ion program at the LHC (estimated MIE TEC $13,000,000) according to planned profiles. The LHC Heavy Ion MIE adds a calorimeter to the CERN A Large Ion Collider Experiment (ALICE) experiment to provide the capability to study jet physics. Participation in the heavy ion program at the LHC will provide U.S. researchers the opportunity to search for states of matter under substantially different conditions than those provided by RHIC, and to obtain additional information regarding the nature of matter that existed during the earliest moments of the universe.

▪ **Other Research**	**—**	**5,014**	**5,181**

In FY 2006, $3,573,000 has been transferred to the SBIR program. This activity includes $4,918,000 for Small Business Innovative Research (SBIR) in FY 2007 and $5,117,000 for SBIR in FY 2008 as well as other established obligations that the Heavy Ion Nuclear Physics subprogram must meet.

Operations	**125,730**	**155,159**	**158,788**
▪ **RHIC Operations**	**116,447**	**143,327**	**146,547**

RHIC operations are supported for an estimated 30-week (91% utilization) running schedule in FY 2008 that greatly expands the opportunities to vary the initial conditions (parameters) for forming the observed new state of matter. Together with the implementation of EBIS and detector upgrades, this will allow the RHIC program to make incisive measurements leading to more definitive conclusions on the discovery of strongly interacting quark gluon matter—the “perfect liquid”—and to establish whether other phenomena, such as a “Color Glass Condensate” or Chiral Symmetry Restoration exists in nature. Program targets and milestones should be achieved in a timely manner.

• **RHIC Accelerator Operations**	**87,693**	**111,000**	**113,976**

Support is provided for the operation ($110,876,000), capital investments ($1,000,000), and improvement ($2,100,000) of the RHIC accelerator complex. This includes the Tandem, Booster, and AGS accelerators that together serve as the injector for RHIC. FY 2008 funding will support about 30 weeks (3,730 hours) of operations. The initial survey work with gold and lighter nuclear beams at the full energy will be largely completed and the experimental program will be dominated by measurement of yields of rarer signals and characterization of “jets”. These

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		

measurements will require higher integrated luminosity and support is provided for R&D of electron beam cooling and other luminosity enhancement technologies. Total funding for facility capital equipment and accelerator improvement (AIP) projects are increased ($+700,000) relative to FY 2007 levels.

	FY 2006	FY 2007	FY 2008
RHIC Hours of Operation with Beam	—[a]	4,080	3,730

- **RHIC Experimental Support** **28,754** **32,327** **32,571**

  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 have reached their initial planned potential and about 1,200 scientists and students from 82 institutions and 19 countries will participate in the RHIC research program in FY 2008. Two detectors will operate in FY 2008 (STAR and PHENIX) that provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. FY 2008 funding will support Experimental Support efforts at the level needed for an estimated 30-week running schedule and to pursue important detector R&D activities. Base capital equipment funding is increased relative to FY 2007 to provide the support for maintaining computing capabilities at the RHIC Computing Facility (RCF) and for instrumentation.

- **Other Operations** **9,283** **11,832** **12,241**

  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 fabrication, other capital alterations and additions, and for buildings and utility systems, needed laboratory equipment, and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and for meeting its requirement for safe and reliable facilities operation, and is increased relative to FY 2007 to cover requirements.

Total, Heavy Ion Nuclear Physics **156,657** **197,512** **203,188**

[a] Non-DOE funding enabled RHIC to operate 2,700 hours in FY 2006.

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ **University Research**	
The increase for University Research grants in FY 2008 will provide support for near constant levels of research effort. The major focus of research will be on the RHIC program with data taking with STAR and PHENIX, and data analysis from all detectors, including Phobos and BRAHMS. A modest effort will also be directed towards research at the LHC heavy ion program at CERN.	+262
▪ **National Laboratory Research**	
• BNL RHIC Research: The FY 2008 budget request supports a near constant level of effort. Funding for capital equipment is maintained as the STAR Time-of-Flight (TOF) MIE is completed, the PHENIX Vertex (VTX) detector MIE continues, and the PHENIX Nose Cone Calorimeter (NCC) and the PHENIX Forward Vertex (FVTX) detector MIEs are initiated.	+214
• Other National Laboratory Research: The FY 2008 increase reflects additional capital equipment funds provided for base research infrastructure ($+1,121,000), of which $1,000,000 is provided for upgrades to LHC detectors that will permit a modest U.S. participation in the heavy ion program at the LHC. These additional funds will ensure that National Laboratory researchers continue to provide adequate support to the RHIC experiments and its upgrades, and to effectively utilize the beam time for research and to train students and young scientists.	+1,404
Total, National Laboratory Research	**+1,618**
▪ **Other Research**	
Increase reflects required SBIR obligations.	+167
Total, Research	**+2,047**
Operations	
▪ **RHIC Operations**	
• The FY 2008 request for Accelerator Operations supports operations of the RHIC facility for an approximate 30-week running schedule to meet the program's scientific goals and performance measures.	+2,976

	FY 2008 vs. FY 2007 ($000)
• Experimental Support: Funding is provided for experimental scientific/technical staff and materials and supplies, and capital equipment that effectively support the maintenance and operation of the PHENIX and STAR detectors at RHIC for a 30-week operating schedule.	+244
Total, RHIC Operations	**+3,220**
▪ **Other Operations**	
Increased support is provided for BNL general plant projects and general purpose equipment to increase the level of effort for FY 2008.	+409
Total, Operations	**+3,629**
Total Funding Change, Heavy Ion Nuclear Physics	**+5,676**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Low Energy Nuclear Physics			
Research			
University Research	17,109	19,113	19,648
National Laboratory Research	22,595	29,789	34,113
Other Research[a]	4,335	5,719	5,761
Total, Research	44,039	54,621	59,522
Operations	23,067	29,278	31,125
Total, Low Energy Nuclear Physics	67,106	83,899	90,647

Description

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:

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.

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 nuclear astrophysics processes such as the production of the chemical elements in the universe, and the explosive dynamics of supernovae.

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 nuclear physics experiments.

Benefits

The Low Energy subprogram supports the mission of the Nuclear Physics program by fostering fundamental research to obtain new insight into the structure of nucleonic matter, the nuclear microphysics of the universe, and fundamental tests for new physics. This subprogram supports a broad range of experiments at two National User Facilities, the Holifield Radioactive Ion Beam Facility (HRIBF) and the Argonne Tandem Linac Accelerator System (ATLAS), one other laboratory accelerator facility (88-Inch Cyclotron at LBNL), university-based accelerators, and non-accelerator based facilities such as the Sudbury Neutrino Observatory (SNO) in Canada and the Kamioka Liquid-scintillator Anti Neutrino Detector (KamLAND) in Japan. The development of advanced accelerator technologies is also

[a] In FY 2006, $1,261,000 has been transferred to the SBIR program. This activity includes $1,344,000 for SBIR in FY 2007, and $1,378,000 for SBIR in FY 2008.

supported, including rare isotope beam R&D relevant to next generation nuclear structure and astrophysics facilities. The Low Energy subprogram is an important source of trained scientific/technical personnel who contribute to a wide variety of nuclear technologies, national security, and environmental quality programs of interest to the DOE.

Supporting Information

Progress in both nuclear structure and nuclear astrophysics studies depends in part upon the availability of rare isotope beams, or beams of short-lived nuclei, to produce and characterize nuclei that lie in unstudied regions of the nuclear chart and are involved in important astrophysics processes. While the U.S. today has facilities with capabilities for these studies, the Department has determined that a facility with next generation capabilities for short-lived radioactive beams will be needed for the U.S. to maintain a leadership role. The Nuclear Physics program is developing a strategic plan for implementing a facility with world-class capabilities that will complement existing and planned rare isotope beam capabilities elsewhere in the world. The National Academy of Sciences (NAS) was charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation rare isotope beam facility, and generated a draft report in December 2006, with a final report expected in early 2007. The NAS report addresses the role of a U.S. world-class rare isotope beam facility. Guidance is being sought from NSAC during the on-going long-range planning process regarding the science opportunities that can be pursued with different combinations of capabilities and configurations for such a facility. The long-range plan will be available by the end of 2007. In FY 2008, support is provided for rare isotope beam R&D and investments in research capabilities at forefront rare isotope beam facilities around the world.

The National User Facilities, HRIBF and ATLAS, are utilized by DOE, NSF, and foreign-supported researchers. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation. Accelerator improvement project (AIP) funds are provided to maintain and improve the reliability and efficiency of operations, and to provide new accelerator capabilities. The 88-Inch Cyclotron at the Lawrence Berkeley National Laboratory is a facility for testing electronic circuit components for radiation “hardness” to cosmic rays, supported by the National Reconnaissance Office (NRO) and the U.S. Air Force (USAF), and for a small in-house research program supported by NP. A Memorandum of Agreement between NP, NRO, and the USAF provides for joint support of the 88-Inch Cyclotron through 2011, and continued utilization of the facility for these activities is proposed for FY 2008. In FY 2008, fabrication continues at Lawrence Berkeley National Laboratory for the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE, a segmented germanium detector array with improved position resolution and efficiency for studies with fast fragment nuclear beams.

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), and Yale University; infrastructure is supported at the University of Washington to enable scientific instrumentation projects to be undertaken. 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 and about 15-25 graduate students at different stages of their education. These students historically have been an important source of 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 and the Nation.

The Low Energy subprogram also supports studies of fundamental interactions and symmetries in selected nuclei: “laboratories” that allow precise 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, such as reactions with and decays of cold neutrons. Such experiments are being prepared to mount at cold and ultra-cold beam lines at the SNS. In FY 2008, fabrication continues for the Fundamental Neutron Physics Beamline (FNPB) MIE at the SNS in preparation for these measurements of fundamental properties of the neutron including the electric dipole moment of the neutron (nEDM). Other experiments do not require the use of accelerators: the SNO detector in Canada is studying the production rate and properties of solar neutrinos, while the KamLAND in Japan is studying the properties of anti-neutrinos produced by nuclear power reactors. The SNO detector will conclude its data taking phase in FY 2007 and the collaboration continues data analysis and reporting in FY 2008. In 2007 KamLAND began a new experimental phase to measure lower energy solar neutrinos following an upgrade of the detector.

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. Spectroscopic studies are now probing the stability and structure of nuclei at the proton dripline, the structure of neutron-rich nuclei, and the surprising stability of rapidly spinning very heavy nuclei. In 1997, the HRIBF facility became operational and now produces over 150 proton-rich and neutron-rich radioactive beams for research. New radioactive beams are being developed to increase the scientific reach of the facility. 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. Current experiments are determining the production and destruction rates for long-lived radioactive species produced by supernovae and measured by gamma-ray observatories in space. In neutrino physics, the SNO experiment was designed and built to search for neutrino flavor oscillations with solar neutrinos. It has been spectacularly successful, showing that neutrinos produced in the core of the sun change their character (oscillate) as they traverse solar matter, and thus have mass. SNO's results confirm that the sun indeed draws its energy from nuclear reactions and the number of neutrinos measured agrees well with solar neutrino emission calculated with current models of the sun. The KamLAND experiment, utilizing reactor produced anti-neutrinos, has also demonstrated neutrino oscillations by not only detecting fewer neutrons than are emitted by the reactors, but also by measuring the anti-neutrino energy spectrum shape. At the present level of understanding of neutrino oscillations, KamLAND and SNO results are in excellent agreement and, after final data analyses, will provide well measured oscillation parameters in the solar sector.

FY 2006 Accomplishments

The 2002 NSAC Long-Range Plan summarized the significant achievements of the Low Energy subprogram that are related to the central questions about nuclear structure, nuclear astrophysics, and fundamental interactions and symmetries; since then accomplishments are summarized yearly in the budget submission. The basic knowledge and understanding in these areas have been further extended by these recent highlights:

- The radioactive nuclear species ^{18}F (fluorine-18) is thought to be produced by some types of exploding stars, and gamma-ray spectrometers in space search for its signatures to provide information on these spectacular stellar events. The success of these searches depends critically on the amount of ^{18}F remaining in the explosion remnants, an amount that is dependent on a web of nuclear reactions that create and destroy ^{18}F. Using a beam of radioactive ^{18}F at HRIBF, researchers have recently measured the rates of two nuclear reactions that contribute to the net production of ^{18}F in novae. They find that the new reaction rates result in almost a factor of two higher production of ^{18}F in a nova envelope, indicating that the number of stars where orbiting gamma-ray observatories might detect ^{18}F could be significantly higher than previously believed.

- The nuclear structure properties of known heavy nuclei are required to accurately predict the existence of, as yet undiscovered, superheavy nuclei. Theoretical predictions of the superheavy nuclei depend on the sequence and energy of proton and neutron single-particle states. These properties are used to predict the major gaps between nuclear levels (shell gaps), which stabilize the heavy nuclei against decay. In experiments at ATLAS, the nuclear structure of the nobelium nuclei $^{250,252,254}No$ is being delineated and the occupation of a proton level that influences the so-called Z=114 shell gap has been observed. These data on nobelium suggest that the Z=114 shell gap is different than has been assumed, and that theoretical calculations predicting a cluster of superheavy nuclei stabilized by the Z=114 shell gap need to be reexamined.
- The discovery and study of the heaviest elements continues to challenge both nuclear physics and nuclear chemistry. Today the identification of a new heavy element can depend on the correct identification of a single atom of that element. Confidence in such a discovery relies on independent confirmation by an independent group, as well as a wealth of systematic information about the reactions on and decays of the nuclei involved. Researchers at LBNL employ the Berkeley Gas-filled Separator (BGS) to select just a few atoms for study from reactions on targets like plutonium. Using the BGS they have recently provided independent confirmation of the production of a new element with 111 protons, measured the excitation functions for production of the known heavy nuclides ^{271}Ds and ^{262}Bh (darmstadtium-271 and bohrium-262), and continued a systematic study of hot fusion reactions—those that release several neutrons—on ^{238}U as a possible mechanism to produce even heavier elements.
- Lorentz invariance states that the laws of physics are the same in different frames of reference even if the frames are moving with a constant velocity with respect to each other. Lorentz invariance is the cornerstone of Einstein's theory of special relativity, and sensitive searches for violations of this proposition are of compelling interest. Recently researchers at the University of Washington used an ingenious torsion pendulum, with an overall non-zero electron spin but essentially no external magnetic field, to search for spin dependent violations of Lorentz invariance. This test is a factor of 100 times more sensitive than previous tests involving electrons, but the group found no evidence that there was a Lorentz invariance violation down to the experiment's sensitivity limit.

FY 2006 Facility and Technical Accomplishments

- The SNO experiment has reported neutrino oscillation results with salt data that confirm the D_2O (water with deuterium instead of hydrogen) neutrino oscillation results. Combined, these results demonstrate that electron neutrinos from the sun oscillate into muon and tau neutrinos and that the total neutrino flux agrees well with theoretical predictions. SNO took data with Neutral Current Detectors (NCDs) in its third and final phase, which has ended.
- A collaboration of LBNL and LLNL scientists have completed the installation and commissioning of the germanium clover detector array and silicon telescope array, STARS. This array is optimized to utilize particle-gamma-ray coincidences to study low energy nuclear structure. This program supports basic research as well as cross-section measurements for stockpile stewardship and homeland security.
- The $^{12}C(alpha, gamma)^{16}O$ reaction is often called the "Holy Grail" of nuclear astrophysics. It is not only important in the stellar production of carbon and oxygen, critical to all life in the universe, but

also determines the fate of a star, ending either as a neutron star or as a black hole. Since the cross sections of this reaction under stellar conditions are extremely small, indirect techniques have been used for measuring its strength. A new ATLAS experiment uses a new approach to the problem by employing for the first time large acceptance gas ionization chambers that eliminate a major source of background which plagued earlier measurements, provides improved detector homogeneity and stability, and results with uncertainties reduced by a factor of two.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Research	**44,039**	**54,621**	**59,522**
▪ **University Research**	**17,109**	**19,113**	**19,648**

Support is provided for the research of about 120 scientists and 94 graduate students at 36 universities. 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 2008 funding for operation of university accelerator facilities and for researchers and students provides support ($18,716,000) for a level of effort near that of FY 2007. Capital equipment at the university accelerator facilities is maintained at FY 2007 levels for investments in experimental instrumentation and enhanced capabilities.

- University researchers conduct programs using the low energy heavy ion beams and specialized instrumentation at the ATLAS and HRIBF National User Facilities. These efforts at the user facilities involve about two-thirds of the university scientists supported by this subprogram.

- Accelerator operations are supported for in-house research programs at the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU), and Yale University. These small university facilities have well-defined and unique physics programs, providing light and heavy ion beams, specialized instrumentation, and opportunities for long-term measurements that complement the capabilities of the national laboratory user facilities. Modest equipment funds are provided for new instruments and capabilities.

  Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements are supported, such as measurements and analyses of data for solar and reactor neutrino rates and the neutrino mass at SNO and KamLAND (jointly with the High Energy Physics program), and development of the fundamental neutron program at the SNS with the Fundamental Neutron Physics Beamline.

▪ **National Laboratory Research**	**22,595**	**29,789**	**34,113**

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

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
• **National Laboratory User Facility Research**	**13,501**	**10,778**	**11,155**

Scientists at ANL and ORNL have major responsibilities for maintaining, improving, and developing instrumentation for research by the user communities at the ATLAS and HRIBF National User Facilities, as well as playing important roles in carrying out research that addresses the NP program's priorities. In FY 2008, funding for ANL and ORNL research at the user facilities is provided to maintain the level of effort for nuclear structure and astrophysics research with emphasis on high priority projects. Support is provided for the following research activities.

- ► 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 the study of nuclei at the extremes of excitation energy, angular momentum, deformation, and isotope stability. Studies are undertaken with the Advanced Penning Trap to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model ($5,893,000).
- ► 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 is being utilized in an experimental program in nuclear astrophysics ($5,262,000).

• **Other National Laboratory Research**	**9,094**	**19,011**	**22,958**

Scientists at BNL, LBNL, LLNL, LANL, and ORNL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments (SNO, KamLAND) directed toward fundamental questions. R&D activities are supported for one or more neutrino-less Double Beta Decay experiments, that will search for the neutrino-less decay mode, to measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle. Funds are provided in FY 2008 to initiate U.S. participation in the fabrication of one of the candidate neutrino-less Double Beta Decay experiments, Cryogenic Underground Observatory for Rare Events (CUORE), located in Italy ($500,000).

Additionally, capital equipment funding is provided to support the ongoing GRETINA, FNPB, and nEDM MIEs, according to planned profiles, and for investments in rare isotope beam capabilities at domestic and international facilities to engage the U.S. community in forefront rare isotope beam research during the development of the next generation U.S. facility in nuclear structure and nuclear astrophysics. Funding for scientific/technical staff ($12,277,000) is provided to maintain near constant levels of effort compared to FY 2007 and is directed at the highest priority research, as described below:

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

- Support is provided for a LBNL research effort that uses beams from the 88-Inch Cyclotron to conduct an in-house research program that includes heavy element nuclear physics and chemistry, and fundamental symmetry studies, for testing and leadership in the fabrication of the Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) detector, for R&D efforts in advanced accelerator technologies and techniques and for neutrino astrophysics and neutrino properties including KamLAND ($5,038,000). The KamLAND experiment in Japan measures the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino "oscillations. The KamLAND experiment has entered a second phase by greatly reducing the detector radioactivity background, enabling it to detect lower energy solar neutrinos. Nuclear Physics participation in KamLAND involves university researchers and LBNL researchers supported by this subprogram.
- The GRETINA MIE, for which fabrication began in FY 2004, is especially important for the study of the nuclear decay and structure of rare isotope nuclei in fast fragmentation beams. The improved position resolution and higher efficiency for high-energy gamma rays compared with presently available gamma-ray detector arrays enable this new detector system to utilize fragmented nuclear beams to open up a new frontier for understanding rare isotope nuclei that may exist in stars and supernovae, but live only fractions of a second. In FY 2008, funding of $4,400,000 is provided to continue fabrication of GRETINA (TEC $17,000,000).
- Support is provided for groups at BNL, LBNL, and LANL that are involved in the SNO experiment, jointly built by Canada, the United Kingdom, and the U.S., to address 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, and implying that the neutrinos have mass. SNO results to date indicate strong evidence for neutrino oscillations. In FY 2004, the third phase of SNO began utilizing neutral current detectors to provide additional detail and confirmatory information on neutrino oscillations. The data collection is planned to be completed in FY 2007; analysis of data and publication of results continue ($2,307,000).
- Support is provided to ORNL to continue to coordinate and play a leadership role in fabrication and development of the scientific program for the FNPB MIE at the SNS. The FNPB project is a beam-line at the SNS that will deliver record peak currents of cold and ultra-cold neutrons for studying the fundamental properties of the neutron, leading to a refined characterization of the weak force. Fabrication began in FY 2004 and continues in FY 2008 with funding of $1,500,000 (TEC $9,200,000).
- Support is provided ($3,000,000) to pursue the measurement of the electric dipole moment of the neutron (nEDM), a high discovery potential experiment at the FNPB (estimated TEC $18,300,000). The measurement of a non-zero electric dipole moment of the neutron, or a stringent upper limit on its value, will significantly constrain extensions of the Standard Model.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

- Funding is provided within the Low Energy subprogram to support research efforts that are also relevant to the nuclear fuel cycle. Additional funding is provided for this effort in the Theory subprogram for Nuclear Data activities. This effort is carried out in collaboration with the Advanced Scientific Computing Research (ASCR) program and other DOE programs, and a joint workshop was conducted in FY 2006 with ASCR to identify the leading scientific issues for nuclear cross sections, nuclear data, and related computations.

- Funding of $500,000 is provided in FY 2008 to initiate fabrication of the CUORE experiment (estimated TEC $10,000,000) to search for neutrino-less double beta decay (DBD). R&D continues on additional technical approaches to DBD. A successful search for this phenomenon will establish that the neutrino is its own antiparticle and determine the absolute neutrino mass scale, both compelling issues for the Standard Model. The DBD project, with one or more prospective experiments, including CUORE, received CD-0 approval in FY 2006, with an estimated TPC range of $10,000,000 to $75,000,000, depending on the option(s) pursued.

- Funding is provided in FY 2008 for investments in rare isotope beam capabilities at domestic and international facilities ($1,000,000) to engage the U.S. community in forefront rare isotope beam research during the development of the next generation U.S. facility in nuclear structure and nuclear astrophysics. Opportunities for investment will be identified during the long-range planning process and could include investments in R&D accelerator capabilities and multiple MIEs.

▪ **Other Research**	**4,335**	**5,719**	**5,761**
• **Generic Rare Isotope Beam R&D**	**3,960**	**4,000**	**4,000**

Funds are provided for R&D activities aimed at development of rare isotope beam capabilities.

• **SBIR and Other**	**375**	**1,719**	**1,761**

In FY 2006, $1,261,000 has been transferred to the SBIR program. This activity includes $1,344,000 for SBIR in FY 2007, and $1,378,000 for SBIR in FY 2008. Funding is also provided for other established obligations including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

Operations	**23,067**	**29,278**	**31,125**
▪ **User Facility Operations**	**22,917**	**25,992**	**27,695**

In FY 2008, support is provided to operate the two National User Facilities, the ATLAS at ANL ($13,767,000) and the HRIBF at ORNL ($13,928,000), for studies of nuclear reactions, structure and fundamental interactions at increased levels compared to FY 2007.

ATLAS provides stable heavy ion beams and selected radioactive ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, Gammasphere, and advanced detectors to study the structure of nuclei at the limits of stability, selected topics in nuclear astrophysics, and fundamental and decay properties of nuclei. In FY 2008, funding supports accelerator operations providing beam hours at FY 2007 levels. Accelerator improvement project funding supports

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

upgrading the accelerator to increase the radioactive beam capabilities of ATLAS with the Californium Rare Ion Breeder Upgrade (CARIBU) project.

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, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector array for nuclear astrophysics studies. In FY 2008, funding supports accelerator operations providing increased beam hours compared to FY 2007, and capital equipment and accelerator improvement project funding supports the continued fabrication of a second source and transport beamline (IRIS2) for radioactive ions, started in FY 2006.

In FY 2007, these low energy facilities will carry out about 80 experiments involving over 600 U.S. and foreign researchers. Planned hours of operation in FY 2007 and FY 2008 with beam are indicated below; the FY 2006 hours are actual beam hours provided:

	FY 2006	FY 2007	FY 2008
ATLAS Hours of Operation with Beam	5,896	5,600	5,600
HRIBF Hours of Operation with Beam	5,215	4,350	5,000
Total Beam Hours for Low Energy Facilities	11,111	9,950	10,600

The actual beam hours provided by ATLAS in FY 2006 exceeded planned operations of 4,380 hours because of decisions to delay a maintenance and cryogenic plant upgrade period from FY 2006 to FY 2007, and to defer replacement of departing personnel, enabling additional beam operations. The actual beam hours provided by HRIBF in FY 2006 exceeded planned operations of 3,650 hours because of a substantial shift from radioactive ion beam (RIB) running to the less costly stable ion beam (SIB) running, permitting additional hours of operations. This unanticipated shift was necessitated by a six-month shutdown of the RIB driver accelerator to accomplish extensive repairs.

	FY 2006	FY 2007	FY 2008
▪ **Other Operations**	**150**	**3,286**	**3,430**

The 88-Inch Cyclotron has been jointly operated (under a Memorandum of Agreement valid through 2011) by the NP program and the National Reconnaissance Office (NRO) and the Air Force (USAF) since FY 2004. The beams of the 88-Inch Cyclotron are used by NP supported researchers for a focused in-house program and for NRO and USAF to simulate cosmic ray damage to electronic components to be used in space. In FY 2008, the NRO and USAF will utilize the 88-Inch Cyclotron for approximately 2,000 hours for their testing program, and NP will utilize it for approximately 3,000 hours for an in-house nuclear physics research program. The NRO and USAF will provide a total of $2,200,000 and NP will provide $3,277,000 for joint operations of the facility in FY 2008. In FY 2006, this funding was included under User Facility Operations.

Funding is also provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.

	FY 2006	FY 2007	FY 2008
Total, Low Energy Nuclear Physics	**67,106**	**83,899**	**90,647**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Research	
▪ **University Research**	
FY 2008 funding supports a near constant level of effort compared to FY 2007. Research concentrates on high priority programs, operations of university accelerators, and non-accelerator initiatives.	+535
▪ **National Laboratory Research**	
• **National Laboratory User Facility Research:** FY 2008 funding supports a constant level of effort compared to FY 2007 for high priority research efforts and activities at the ATLAS and HRIBF, which is needed for effective and productive exploitation of the beams at these user facilities.	+377
• **Other National Laboratory Research:** Increased FY 2008 funding provides a cost of living adjustment for scientific/technical staff to support high priority research efforts ($+488,000) including funding for research activities relevant to the design of next generation nuclear reactors. Funding is also increased for capital equipment ($+3,459,000) for the ongoing fabrication of the GRETINA, FNPB, and nEDM MIEs according to project plans, the initiation of the new CUORE MIE, and investments in rare isotope beam capabilities.	+3,947
Total, National Laboratory Research	**+4,324**
▪ **Other Research**	
The increase reflects required SBIR and other obligations.	+42
Total, Research	**+4,901**
Operations	
▪ **User Facility Operations** budget supports operations of HRIBF ($+359,000) and ATLAS ($+344,000) at operating levels near that of FY 2007; Capital Equipment and AIP investments increase ($+1,000,000) for instrumentation necessary to carry out the experimental program at HRIBF to support continued fabrication of a second source and transport beamline for radioactive ions to enable increased hours of radioactive beams on target with higher beam intensities, and at ATLAS to develop an ion source for unique capabilities for radioactive beams.	+1,703
▪ **Other Operations** maintains NP's share of the 88-Inch Cyclotron operations at the FY 2007 level of effort.	+144
Total, Operations	**+1,847**
Total Funding Change, Low Energy Nuclear Physics	**+6,748**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Nuclear Theory			
Theory Research			
University Research	11,132	14,229	14,553
National Laboratory Research	10,636	11,718	12,150
Scientific Discovery through Advanced Computing (SciDAC)	1,485	2,500	2,588
Total, Theory Research	23,253	28,447	29,291
Nuclear Data Activities	5,099	6,901	7,114
Total, Nuclear Theory	28,352	35,348	36,405

Description

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:

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.

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 of a "comprehensive model" for nuclei that is applicable across the entire periodic table.

What are the properties of hot nuclear matter? The properties of hot, dense nuclear matter, is the central topic of research at the 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 are 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 for this new state of matter, along with other new phenomena. A key goal of the theoretical program is to establish knowledge of the QCD phase diagram of bulk nuclear matter.

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.

Is there new physics beyond the present 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.

Benefits

The Nuclear Theory subprogram cuts across all components of the Nuclear Physics mission to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy. The theory groups and individual researchers at universities and DOE national laboratories strive to improve the theoretical techniques and gain new insights used to interpret data gathered by Nuclear Physics supported user facilities and the non-accelerator based experimental programs. In addition, theorists play a crucial role in identifying and articulating the scientific questions that lead to the construction of new facilities, and in motivating the upgrades to existing facilities. By doing so, they not only advance our scientific knowledge and technologies, especially in the area of large scale computing, but serve to train the scientific/technical workforce needed for this research and indeed for an increasingly technological society. The mission of the Nuclear Data Program, included within the Theory subprogram, is also directly supportive of the DOE's missions for nuclear-related national security, energy, and environmental quality.

Supporting Information

The research of this subprogram 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 also sponsors the national Institute for Nuclear Theory (INT), based at the University of Washington, in Seattle, 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. 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, condensed matter physics and particle physics.

The subprogram is responding to the need for large dedicated computational resources for Lattice Quantum Chromodynamics (LQCD) calculations that are critical for understanding the experimental results from RHIC and TJNAF. Together with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs, an approximately 5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. This platform enabled U.S. researchers to stay competitive with other worldwide efforts in computational QCD research while developing a larger-scale hardware platform. In a joint effort with HEP, development of large-scale facilities (about an additional 13 teraflops) began in FY 2006 to provide computing capabilities based on commodity cluster systems.

The program is enhanced through interactions with complementary programs overseas, efforts supported by the National Science Foundation, programs supported by the High Energy Physics program and Japanese supported theoretical efforts related to RHIC at the RIKEN Center at Brookhaven National Laboratory. JUSTIPEN, the Japan U.S. Theory Institute for Physics with Rare Isotope Nuclei, was formed at RIKEN (in Wako, Japan) in FY 2006. JUSTIPEN's purview will be in the area of the physics of (or with) rare isotope nuclei, including nuclear structure and reaction theory, nuclear astrophysics, and tests of the standard model using rare isotope nuclei. U.S. participation in JUSTIPEN is in the form of travel grants and subsistence grants to individual theorists interested in collaborating with Japanese scientists.

Theory subprogram activities 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.

FY 2006 Accomplishments

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:

- *Studies of the nucleon-nucleon interaction on the lattice:* This year witnessed a major step toward one of the ultimate goals of nuclear physics – to compute the properties and interactions of nuclei directly from Quantum Chromodynamics (QCD), the underlying theory of the strong interactions. The low energy scattering of two pions with fully dynamical QCD and input quark masses near the physical masses was calculated and agreed with indirect measurements of this important quantity. A similar calculation of the low energy scattering of two nucleons was performed with different values of the mass of unphysically heavy quarks and extrapolated to the measured quantity to learn the quark mass dependence of this theoretical result. Thus, this preliminary and pioneering calculation gives a hint of how nuclear processes depend upon the fundamental constants of nature (quark masses in this case). Further development of this accomplishment would enable the computation of strong-interaction processes of importance in environments not attainable in the laboratory, such as in the interior of neutron stars. These results were obtained by a group of researchers at universities and at LBNL using the configurations partially motivated by high energy needs and calculated on the special purpose computers (QCDOC and clusters of commodity machines) at BNL, FNAL, and TJNAF.
- *Ab initio calculation of a nuclear reaction important in astrophysics and fundamental symmetries:* Precise predictions of the production rate of solar neutrinos from the weak decay of ^{8}B are important for testing solarmodels, and for limiting the allowed neutrino mixing parameters including possible contributions of sterile species. The predicted ^{8}B production rate is based on solar model calculations that incorporate measured reaction rates for each of the solar burning steps following the initial p+p reaction, the most uncertain of which is the ^{7}Be (p,γ)^{8}B rate. This rate is characterized by the ^{7}Be(p,γ)^{8}B S-factor which is the subject of intense experimental and theoretical investigation. The first *ab initio* prediction of the ^{7}Be(p,γ)^{8}B S-factor has been achieved at Lawrence Livermore National Laboratory this year and found to be in very good agreement with a recent direct measurement at the NP Center of Excellence at the University of Washington. The nuclear wave functions of the bound states of ^{7}Be and ^{8}B were calculated within the *ab initio* No-Core-Shell-Model framework using a nucleon-nucleon interaction which fits the nucleon-nucleon data to high precision. The "overlap" of the ^{7}Be+p and ^{8}B was determined in two different ways and found to have a small effect on the result; hence one styles this as the first *ab initio* reaction calculation with nuclei more massive than ^{4}He.

- *Formation of the elements in the end game of stars:* Researchers at ORNL with NP supported university collaborators (and others from overseas) have adapted a technique used previously to model the formation of elements (nucleosynthesis) in the Big Bang to the study of nucleosynthesis in the final explosive stages of stellar evolution. It is believed that the heavy elements are born in the violent environment of gravitational core collapse supernovae, ordinary novae, and X-ray bursts and γ-ray bursts, but the details of these processes and the resulting abundances of the nuclides produced remain to be fully worked out. In particular, the sensitivity of abundances to uncertainties in reaction rates measured, yet to be measured at HRIBF or similar facilities, or simply immeasurable is difficult to determine without taking into account all reaction rates in a systematic way. The Monte Carlo technique chooses a random enhancement factor for each reaction rate within the quoted uncertainty, does a complete calculation for the entire chain of reactions, and calculates the final abundances for this trial. After thousands of trials (like flipping a coin multiple times to determine the probability of landing heads up) the average abundances with uncertainties emerge and can be compared with the abundances observed in the universe. This is the significant theoretical step which allows the theorist to identify the most significant reaction or reactions in the chain and make recommendations for priorities among the expensive experiments at the radioactive beam facilities. As these calculations are done in the best educated guesses of the explosive environment that nucleosynthesis takes place, this technique offers for the future more refined studies of that very environment. Perhaps ultimately astrophysicists can even determine where in the universe the so-called r-process nucleosynthesis of the heavy elements takes place.

FY 2006 Technical Accomplishments

- Theoretical calculations for Quantum Chromodynamics (QCD) require enormous computation resources with architectures that are optimized to address this class of nuclear physics problem. NP, with High Energy Physics, international participants, and industrial partners, has contributed to a massively parallel computing technology called QCD On-a-Chip (QCDOC). QCDOC utilizes a six-dimensional machine mesh and system-on-a-chip technology, offering a factor of ten improvement in price per unit performance. The present QCDOC machines are calculating the configurations which are used in final QCD calculations of interest to nuclear and high energy physicists. Furthermore, elements of the QCDOC technology have been adapted by industry and are now employed within the DOE complex and elsewhere as the highest performance computing platforms commercially available.

Detailed Justification

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Theory Research	**23,253**	**28,447**	**29,291**
▪ **University Research**	**11,132**	**14,229**	**14,553**

The research of about 145 university scientists and 105 graduate students is supported through 56 grants at 43 universities in 28 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 postdoctoral support is a major element of this program. In FY 2008, funding supports a near constant level of effort compared with FY 2007 for theoretical efforts needed for interpretation of experimental results obtained at the NP facilities. The theoretical efforts are optimized to focus on the high priority activities which are aligned with SC Strategic Plan milestones. Following a recommendation of the NSAC Theory Review subcommittee

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

in its report "A Vision for Nuclear Theory," support continues for investments in Lattice QCD computer capabilities in a joint effort with High Energy Physics.

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 (annual budget approximately $2,000,000). 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, a recent program focused on nuclear structure near the limits of stability where important features of the nuclear many-body problem are magnified and principal uncertainties in the theoretical description of nuclei can be effectively studied. Another program concentrated on the exploration of hadron structure and spectroscopy using Lattice QCD, exploiting various theoretical approaches in the context of lattice calculations to obtain insight into hadron structure, to calculate observables relevant to current experiments, and to guide the future experimental program. Often the key papers on the program subjects are either written during the INT programs or based on discussions that took place at the INT.

	FY 2006	FY 2007	FY 2008
▪ **National Laboratory Research**	**10,636**	**11,718**	**12,150**

Research programs are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). In FY 2008, funding supports a constant level of effort for scientific/technical staff compared with FY 2007 in order to address theoretical issues important for advancing the national nuclear physics program. 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 postdoctoral associates.

	FY 2006	FY 2007	FY 2008
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	**1,485**	**2,500**	**2,588**

Scientific Discovery through Advanced Computing (SciDAC) is an SC program to address major scientific challenges that require advances in scientific computing using terascale resources. Following the re-competition of SciDAC projects in FY 2006, the Nuclear Physics Theory subprogram currently supports efforts in nuclear astrophysics, grid computing, Lattice Gauge QCD theory, and low energy nuclear structure and nuclear reaction theory. NP partners in various combinations with HEP, ASCR, and NNSA on these projects.

	FY 2006	FY 2007	FY 2008
Nuclear Data Activities	**5,099**	**6,901**	**7,114**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the physics community and the Nation. The focal point for its national and international activities is the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Funding in FY 2008 supports a near constant level of effort at FY 2007 levels for Nuclear Data activities. The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and national laboratories that perform 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 2006	FY 2007	FY 2008
	(dollars in thousands)		

Funding is also provided to support ongoing research efforts that are also relevant to nuclear fuel cycle, including covariant matrix studies, cross section evaluations, relevant computations, and other activities. Funding to support related efforts is provided in the Low Energy subprogram. This effort is carried out in collaboration with the ASCR program, and a joint workshop was conducted in FY 2006 to identify the leading scientific issues.

	FY 2006	FY 2007	FY 2008
Total, Nuclear Theory	**28,352**	**35,348**	**36,405**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Theory Research	
▪ **University Research**	
FY 2008 funding supports personnel at a near constant level of effort to carry out the national Nuclear Physics program. Resources will be focused on the theoretical understanding of the research that was identified in SC Strategic Plan Milestones and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory.	+324
▪ **National Laboratory Research**	
FY 2008 funding provides a constant level of theoretical effort needed to address the national nuclear physics program. Research will be directed toward achieving the scientific goals of the Nuclear Physics program, including the continuation of the Lattice Gauge Quantum Chromodynamics initiative with HEP.	+432
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
FY 2008 funding allows for continued support in the most promising areas for progress in nuclear physics with terascale computing capabilities.	+88
Total, Theory Research	**+844**
Nuclear Data Activities	
FY 2008 funding supports a near constant level of effort compared to FY 2007.	+213
Total Funding Change, Nuclear Theory	**+1,057**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Construction			
07-SC-02, Electron Beam Ion Source, BNL	—	7,400	4,200
06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	500	7,000	13,500
06-SC-02, Electron Beam Ion Source (PED), BNL	1,980	120	—
Total, Construction	2,480	14,520	17,700

Description

This subprogram provides for Construction and Project Engineering and Design that is needed to meet overall objectives of the Nuclear Physics program.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
07-SC-02, Electron Beam Ion Source, BNL	**—**	**7,400**	**4,200**

The final year of funding is requested to continue construction of the Electron Beam Ion Source (EBIS) project with a TEC of $13,700,000 and TPC of $14,800,000 and completion in FY 2010. EBIS is supported jointly by NP and NASA and will replace the high maintenance tandems as the RHIC pre-injector, leading to more cost effective operations and new research capabilities. NASA is contributing an additional $4,500,000 above the DOE TPC. EBIS received CD-2 and CD-3 approval in FY 2006. Findings of a Technical, Cost, Schedule and Management Review conducted in FY 2006 were utilized in the formulation of the FY 2008 budget request.

06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	**500**	**7,000**	**13,500**

Funding is requested to complete PED activities for the 12 GeV CEBAF Upgrade (PED TEC $21,000,000). The upgrade was identified in the 2002 NSAC Long-Range Plan as one of the highest priorities for Nuclear Physics and is a near-term priority in the SC 20-Year Facilities Outlook. The upgrade will enable scientists to address one of the greatest mysteries of modern physics—the mechanism that confines quarks together. The project received CD-1 approval in February 2006. The proposed cost and schedule profiles reflected in this FY 2008 budget request are consistent with the recommendations made by the DOE Office of Project Assessment Review performed in FY 2006.

06-SC-02, Electron Beam Ion Source (PED), BNL	**1,980**	**120**	**—**

PED funding is completed in FY 2007 and the final year of construction funding is requested in FY 2008 in line item 07-SC-02 (see above). EBIS received CD-2 and CD-3 approval in the fourth quarter of FY 2006.

Total, Construction	**2,480**	**14,520**	**17,700**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
07-SC-02, Electron Beam Ion Source, BNL	
Funds are provided for the final year of construction consistent with the CD-2 approved baseline for the Electron Beam Ion Source (EBIS) to replace the aging Tandem Van de Graaff as the heavy ion source for the RHIC complex.	-3,200
06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	
Support is provided to complete Project Engineering and Design for the 12 GeV CEBAF Upgrade.	+6,500
06-SC-02, Electron Beam Ion Source (PED), BNL	
Project engineering and design (PED) funding for EBIS was completed in FY 2007.	-120
Total Funding Change, Construction	**+3,180**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	7,342	7,870	8,147
Accelerator Improvements Projects	4,873	6,200	7,300
Capital Equipment	22,045	30,421	35,853
Total, Capital Operating Expenses	34,260	44,491	51,300

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unappro-priated Balance
07-SC-02, Electron Beam Ion Source, BNL	13,700[a]	—	—	7,400	4,200	—
06-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	21,000[b]	—	500	7,000	13,500	—
06-SC-02, Electron Beam Ion Source (PED), BNL	2,100[a]	—	1,980	120	—	—
Total, Construction			2,480	14,520	17,700	

[a] Includes the TEC for design and construction. Design funding is in 06-SC-02. The project was baselined with CD-2 approval in FY 2006 with a Total Estimated Cost of $13,700,000. CD-3 was approved in FY 2006.

[b] The full Total Estimated Cost (design and construction) ranges between $205,000,000 and $281,500,000 and includes the $21,000,000 for Project Engineering and Design (PED) provided in 06-SC-01; the full Total Project Cost (design and construction) ranges between $225,000,000 and $306,000,000. These estimates are based on preliminary data and should not be construed as a project baseline. CD-1 was approved in FY 2006.

[a] Design TEC estimate only. See 07-SC-02.

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
STAR Time-of-Flight, BNL (61PB)	4,800[a]	4,800[a]	—	2,400	2,424[a]	—	FY 2009
GRETINA Gamma-Ray Detector, LBNL (41NL)	18,200[b]	17,000[b]	3,500	3,000	3,900	4,400	FY 2010
Fundamental Neutron Physics Beamline, ORNL (41NM)	9,288[c]	9,200[c]	2,200	1,900	1,500	1,500	FY 2010
PHENIX Silicon Vertex Tracker, BNL (71RD)	4,600[d]	4,600[d]	—	—	2,000	2,000	FY 2010
Heavy Ion LHC Experiments, LBNL (71RC)	13,295[e]	13,000[e]	—	—	1,000	2,000	FY 2012
Neutron Electric Dipole Moment (nEDM), LANL (71RE)	18,480[f]	18,300[f]	—	—	1,300	3,000	FY 2015
Cryogenic Underground Observatory for Rare Events (CUORE), LBNL	10,000[g]	10,000[g]	—	—	—	500	FY 2012
PHENIX Forward Vertex Detector, BNL	4,950[h]	4,950[h]	—	—	—	1,400	FY 2011
PHENIX Nose Cone Calorimeter, BNL	4,700[h]	4,700[h]	—	—	—	1,000	FY 2011
Total, Major Items of Equipment				7,300	12,124	15,800	

[a] A project Status Review was conducted in September 2006 to assess project plans and performance. The FY 2006 rescission of $24,000 for this MIE was restored during FY 2006 after submission of the FY 2007 Budget negating the need to restore the $24,000 in FY 2007. FY 2007 funding will be adjusted accordingly upon enactment of the FY 2007 Appropriation.

[b] The preliminary TEC is within the $13,000,000 to $18,000,000 range approved at CD-0 and CD-1. The TEC is preliminary and will be baselined at CD-2. The CD-2a for long lead procurements was approved in June 2005. CD-2 for the project as a whole is planned for July 2007.

[c] The TEC of $9,200,000 is within the $8,000,000 to $11,000,000 range approved at CD-0 and has been baselined at CD-2.

[d] The project was baselined at a Technical, Cost, Schedule and Management Review in 2006. Under a year-long FY 2007 Continuing Resolution, new starts may be deferred. Cost and schedule impacts will be determined after passage of an appropriation.

[e] CD-0 was approved in November 2005 with a preliminary TPC range of $5,000,000 - $16,000,000. The TEC and TPC are preliminary and will be baselined at CD-2. Under a year-long FY 2007 Continuing Resolution, new starts may be deferred. Cost and schedule impacts will be determined after passage of an appropriation.

[f] CD-0 was approved in November 2005 with a preliminary TPC range of $12,000,000 - $18,300,000. The TEC and TPC are preliminary and will be baselined at CD-2. Under a year-long FY 2007 Continuing Resolution, new starts may be deferred. Cost and schedule impacts will be determined after passage of an appropriation.

[g] CD-0 for multiple candidate double beta decay experiments was approved in November 2005 with a preliminary TPC range of $10,000,000 - $75,000,000. The TEC and TPC are preliminary and will be baselined at CD-2. CUORE represents one of the candidate experiments. R&D efforts continue on a detector utilizing a different technology.

[h] The TEC and TPC are preliminary and will be baselined at a Technical, Cost, Schedule and Management Review.

Fusion Energy Sciences

Funding Profile by Subprogram

	(dollars in thousands)		
	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Fusion Energy Sciences			
Science	148,642	154,213	159,529
Facility Operations	104,210	121,555	237,004
Enabling R&D	27,831	43,182	31,317
Total, Fusion Energy Sciences	280,683[a]	318,950	427,850

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The Fusion Energy Sciences (FES) program is 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.

Benefits

Total world energy consumption has increased by more than 50% during the past 25 years, and given the rapid pace of world economic growth, this trend is expected to continue. With decreasing fossil fuel resources and increasing awareness that the use of fossil fuels is harming the environment, finding new sources of energy to meet our future energy needs is one of the greatest scientific challenges of the 21st century. Fusion, which is one of the few fundamentally new sources of energy under development by the Department of Energy, has the potential to provide a significant fraction of the world's energy needs by the end of this century.

The fusion process is conceptually simple but very difficult to achieve in practice. Fusion occurs when deuterium and tritium, two isotopes of hydrogen, combine or fuse to form a single helium nucleus. During this fusion process, some of the mass of the deuterium and tritium nuclei is converted into a large amount of energy. Fusion is difficult to achieve on earth because the deuterium and tritium must be confined and heated to a temperature greater than 100 million degrees Celsius, at which point the deuterium and tritium exist in the plasma state. Plasmas are very different from ordinary gases and are subject to a wide variety of collective instabilities that are only partially understood at the present time. Understanding and learning to control these instabilities is a major scientific challenge to achieving practical fusion power.

The ultimate goal of fusion research is an attractive, long-term source of energy. The fusion fuels, deuterium and tritium, are plentiful and may be obtained from sources as common and abundant as sea water and lithium from the earth's crust. Successful development of fusion power would greatly reduce

[a] Total is reduced by $2,906,000 for a rescission in accordance with P.L. 109–148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006; $6,215,000, which was transferred to the SBIR program; and $746,000, which was transferred to the STTR program.

concerns over imported oil, rising gasoline prices, smokestack pollution, global warming, and other problems associated with our dependence on oil and other fossil fuels and would help to meet the energy needs of all mankind for centuries.

U.S. participation in the international ITER Project, a Presidential initiative, is a bold next step in fusion research. ITER is designed to produce, control, and sustain a burning plasma, a plasma whose high temperature is maintained by the alpha particles produced by fusion reactions in the plasma. The European Union, China, India, Japan, Korea, Russia, and the U.S. signed a 35-year agreement to construct, operate, and decommission the ITER facility on November 21, 2006. Research on ITER is expected to provide sufficient information on the complex science of burning plasmas to make a definitive assessment of the scientific feasibility of fusion power.

A science-based portfolio approach is the most effective approach to ensuring the success of ITER and continuing the scientific discovery needed to achieve commercial fusion power. While the knowledge base is now in hand to build ITER, a strong core research program consisting of experiments on existing facilities, comprehensive theory and simulation, and technology development is needed to make the exciting discoveries that will identify successful operating regimes for ITER and develop the skilled workforce needed to carry out research on ITER. A portfolio approach also advances our knowledge of plasma physics and associated technologies, thereby yielding near term benefits in a broad range of scientific disciplines, such as plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative materials coatings, space propulsion, neutron sources that can enable detection of explosives of highly enriched uranium for homeland security, and efficient destruction of chemical wastes.

Strategic and GPRA Unit Program Goals

The Department's Strategic Plan identifies five Strategic Themes (one each for nuclear, energy, science, environmental, and management aspects of the DOE mission) plus 16 Strategic Goals that tie to the Strategic Themes. The FES program supports the following goals:

Strategic Theme 3, Scientific Discovery & Innovation
Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.

Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

The FES program has one GPRA Unit Program goal which contributes to Strategic Goal 3.1 and 3.2 in the "goal cascade":

GPRA Unit Program Goal 3.1/2.49.00: Bring the Power of the Stars to Earth—Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels our Sun.

Contribution to Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science

The FES program contributes to these Strategic Goals by managing a program of fundamental research into the nature of fusion plasmas and the means for confining plasma to yield energy. This program includes: (1) exploring basic issues in plasma science; (2) developing the scientific basis and computational tools to predict the behavior of magnetically confined plasmas; (3) using the advances in tokamak research to enable the initiation of the burning plasma physics phase of the FES program; (4) exploring innovative confinement options that offer the potential to increase the scientific understanding and to improve the confinement of plasmas in various configurations; (5) investigation of non-neutral plasmas and high energy density physics; and (6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals.

These activities require operation of a set of unique and diversified experimental facilities, including smaller-scale devices at universities involving individual Principal Investigators, larger national facilities that require extensive collaboration among domestic institutions, and an even larger, more costly experiment that requires international collaborative efforts to share the costs and gather the scientific and engineering talents needed to undertake such an experiment. These facilities provide scientists with the means to test and extend theoretical understanding and computer models—leading ultimately to an improved predictive capability for fusion science.

The following indicators establish specific long term (10 year) goals in scientific advancement to which the FES program is committed and against which progress can be measured.

- **Predictive Capability for Burning Plasmas:** Progress toward developing a predictive capability for key aspects of burning plasmas using advances in theory and simulation benchmarked against a comprehensive experimental database of stability, transport, wave-particle interaction, and edge effects.
- **Configuration Optimization:** Progress toward demonstrating enhanced fundamental understanding of magnetic confinement and improved basis for future burning plasma experiments through research on magnetic confinement configuration optimization.
- **High Energy Density Plasma Physics:** Progress toward developing the fundamental understanding and predictability of high energy density plasma physics.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.49.00, Bring the Power of the Stars to Earth			
Fusion Energy Sciences	280,683	318,950	427,850

Annual Performance Results and Targets

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
GPRA Unit Program Goal 3.1/2.49.00 (Bring the Power of the Stars to Earth)					
Science[a]					
N/A	N/A	Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2005, FES measured plasma behavior in Alcator C-Mod with high-Z antenna guards and input power greater than 3.5 MW.[b] [Met Goal]	Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod, and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2006, FES injected 2 MW of neutral power in the counter direction on DIII-D and began physics experiments. [Met Goal]	Conduct experiments on major fusion facilities leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2007, FES will measure and identify magnetic modes on NSTX that are driven by energetic ions traveling faster than the speed of magnetic perturbations (Alfvén speed); such modes are expected in burning plasmas such as ITER.	Conduct experiments on major fusion facilities leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2008, FES will evaluate the generation of plasma rotation and momentum transport, and assess the impact of plasma rotation on stability and confinement. Alcator C-Mod will investigate rotation without external momentum input, NSTX will examine very high rotation speeds, and DIII-D will vary rotation speeds with neutral beams. The results achieved at the major facilities will provide important new data for estimating the magnitude of and assessing the impact of rotation on ITER plasmas.

[a] The performance metrics for Science are not PART measures.
[b] This target addresses issues related to first wall choices and the trade-offs between low-Z and high-Z materials. This choice can affect many important aspects of tokamak operation, including: impurity content and radiation losses from the plasma; hydrogen isotope content in the plasma and retention in the walls; and disruption hardiness of device components. All of these issues are significant when considering choices for next step devices to study burning plasma physics, especially ITER. Definitive experimental results have been compared to model predictions, and are documented in a *Target Completion Report* submitted in September 2005.

FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Targets	FY 2008 Targets
N/A	N/A	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2005, FES simulated nonlinear plasma edge phenomena using extended MHD codes with a resolution of 20 toroidal modes. [Met Goal]	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2006, FES simulated nonlinear plasma edge phenomena using extended MHD codes with a resolution of 40 toroidal modes. [Met Goal]	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2007, improve the simulation resolution of linear stability properties of Toroidal Alfvén Eigenmodes driven by energetic particles and neutral beams in ITER by increasing the number of toroidal modes used to 15.	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2008, improve the simulation resolution of ITER-relevant modeling of lower hybrid current drive experiments on Alcator C-Mod by increasing the number of poloidal modes used to 2,000 and the number of radial elements used to 1,000 using the leadership class computers at ORNL.
Facility Operations					
Kept deviations in weeks of operation for DIII-D and Alcator C-Mod within 10% of the approved plan. NSTX did not meet the target because of a coil joint failure. [Goal partially met.]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.[Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.
Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10% of approved baselines. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.

Status of ITER Activities

The FES program is pushing the boundaries in large scale international scientific collaboration. With the support of a Presidential Initiative, FES is actively leading the U.S. effort to provide components as in-kind contributions, personnel, cash, and contingency in support of ITER—an international project to build and operate the first fusion science facility capable of producing a sustained burning plasma. The mission for ITER is to demonstrate the scientific and technological feasibility of fusion energy. The site selection for the international ITER Project, Cadarache, France, in the European Union, was a major six-party decision on June 28, 2005, at a Ministerial-level meeting in Moscow, Russia.

- **International Negotiations Leading to the Seven Parties Signing Ceremony, November 2006:**

  International negotiations on ITER resulted in the completion of major milestones for the international ITER Project, including: (a) designation of the Director General, a Japanese candidate, chosen to lead the ITER organization, (b) designation of the Principal Deputy Director General, a European Union candidate, chosen to serve as project manager, (c) India joining ITER as a full non-host party, (d) finalization of the procurement allocations to all parties, and (e) completion of the text of the ITER Agreement. Following these milestones, the seven ITER parties of China, the European Union, India, Japan, Korea, Russia, and the United States initialed the Agreement on May 24, 2006, in Brussels to signify that the text was final.

  From the point of initialing until the signing ceremony, held on November 21, 2006 in Paris, France, it was the responsibility of each party delegation to present the final initialed text to their respective governments for further approval. For the U.S., the Agreement and supporting documentation was submitted to Congress in accordance with the Energy Policy Act of 2005, Section 972 (c) for a 120-day review period. The signing of the Agreement confirmed the multilateral commitment for ITER and will be followed by ratification or formal acceptance of the Agreement and entry into force.

- **Management for the International ITER Organization:**

  Significant progress has been made in terms of personnel assigned to the ITER Organization and plans for the establishment of the overall management structure. In May 2006, prior to the parties initialing the Agreement, the Director General Nominee (Director General) and the Principal Deputy Director General Nominee (Principal Deputy Director General) distributed the provisional management structure for the ITER Organization. As expected, the Director General will provide overall leadership of the ITER Organization. The Principal Deputy Director General will support the Director General on all matters related to management of the ITER Organization, especially those matters dealing with construction, supervision of project execution, and managing discussions with the seven parties regarding their deliverables. The U.S. is particularly pleased to note that the Principal Deputy Director General, a European Union candidate, was a member of the senior management team of the Spallation Neutron Source located at Oak Ridge National Laboratory.

  During a meeting among the seven parties in July 2006, the Director General of the ITER organization announced the selection of the Deputy Director General appointments. These key management positions cover the following areas: (a) Environment, Safety & Health (ES&H) including Quality Assurance and Licensing; (b) Administration; (c) Fusion Science and Technology; (d) Tokamak; (e) Central Engineering and Plan Support; and (f) ITER Control, Data Access and Communications Systems (CODAC), Heating Systems and Diagnostics. Most of the Deputy Directors General are now on site. Other key aspects of the ITER Organization structure include: the ITER Council, which will serve an oversight function and will be comprised of members from each party to oversee the Director General, and the functions of the ITER Organization Management

Advisory Committee, Scientific and Technology Advisory Committee, Senior Scientific and Legal Advisors, and the Project Office.

- **Levels of Participation in the International Project:**

  As a result of the international negotiations, a revised allocation of hardware deliverables from each party, including India, was agreed upon. Collectively, the ITER parties are able to accomplish the originally planned ITER construction scope of work and, in addition, provide a contingency or "Central Reserve" for the shared activities at the ITER site, such as design, system integration, provision of infrastructure, and installation of hardware. The provision of a Central Reserve for the ITER Organization, which resulted when India joined, is consistent with sound project management principles. Such contingency resources are to be accessed at the request of the Director General and with subsequent approval by the ITER Council. The amount of funding required by each party remains the same. For each of the 6 non-hosts, including the United States, what was previously a $^{1}/_{10}$ (10%) share of a total that excluded contingency for the site activities, now becomes a $^{1}/_{11}$ share (about 9.1%) of the ITER hardware, personnel, and cash plus contingency for the site activities. The corresponding host share is $^{5}/_{11}$ (45.4%).

- **Next Major Steps for the Seven ITER Parties:**

  The steps following the Ministerial-level signing of the Agreement held on November 21, 2006, include ratification or formal acceptance of the Agreement by mid-2007 and entry into force and formal establishment of the ITER Organization by late 2007.

- **U.S. Contributions to ITER:**

  The U.S. Contributions to ITER Major Item of Equipment (MIE) project is managed by the U.S. ITER Project Office (USIPO) located at the Oak Ridge National Laboratory (ORNL) with current partnering laboratories Princeton Plasma Physics Laboratory (PPPL) and Savannah River National Laboratory (SRNL). In May 2006, the Project Manager relocated from PPPL to ORNL. The USIPO staff includes the Project Manager, Deputy Project Manager, Project Controls Manager, Project Engineering Manager, Procurement Manager, Business Manager, Environmental, Safety and Health (ES&H) and Quality Assurance (QA) Manager, Chief Scientist, Chief Technologist, and Managers for the work breakdown structure elements of magnet systems, first wall and shield systems, port limiters, tokamak cooling water systems, vacuum pumping and fueling systems, ion cyclotron heating system, electron cyclotron heating system, tritium plant exhaust processing system, electric power systems, and diagnostics.

  In FY 2005 and FY 2006, and in accordance with DOE Order 413.3A, the FES program and the USIPO have been preparing for Critical Decision 1 (CD-1), Approve Alternative Selection and Cost Range, in late FY 2007–early FY 2008 and Critical Decision 2b (CD-2b), Approve Performance Baseline, in late FY 2008. In order to accommodate the necessary U.S. long-lead procurements in FY 2008, CD-2a/3a will be performed in conjunction with CD-1. It is important that the schedule for the Critical Decision milestones is consistent with the international ITER Project schedule, and that the schedule benefits from activities of the International ITER Project such as the initial design review to be conducted by the Director General and Principal Deputy Director General beginning in early 2007. The schedule for Critical Decision 2b is dependent on the ability of the international ITER Organization to finalize the design and schedule for the ITER Project—both of which affect the establishment of the performance baseline of the U.S. Contributions to ITER project.

  The Total Project Cost (TPC) for the U.S. Contributions to ITER MIE project remains unchanged and is described in more detail in later sections of the FES budget. Funding in FY 2008 provides for

$149,500,000 for Total Estimated Cost (TEC) activities and $10,500,000 for Other Project Costs (OPC) activities. The funding profile maintains the TPC of $1,122,000,000, but does include shifts in OPC and TEC funding.

In accordance with the Energy Policy Act of 2005, Section 972(c)(5)(C), the Department has submitted to Congress the following reports: (1) A ‘Plan for U.S. Scientific Participation in ITER’; (2) A report describing the management structure of the ITER and estimate of the cost of U.S. participation; and (3) A report describing how U.S. participation in ITER will be funded without a funding reduction in other SC programs. The Department’s FY 2008 budget request provides for increases across the Office of Science (SC) and supports the ITER request of $160,000,000 almost entirely from new funds in the FES budget request.

In support of ITER and the U.S. Contributions to ITER MIE project, FES is placing increased emphasis on its national burning plasma program—a critical underpinning of the fusion science in ITER. FES plans to enhance burning plasma research efforts across the U.S. domestic fusion program by:

- Providing ITER R&D support both in physics and technology and exploring new modes of improved or extended ITER performance;
- Developing safe and environmentally attractive technologies necessary for ITER;
- Exploring fusion simulation efforts that examine the complex behavior of burning plasmas in tokamaks, which will impact the planning and conduct of experimental operations in ITER;
- Conducting experiments on our national science facilities with diagnostics and plasma control that can be extrapolated to ITER; and
- Integrating all that is learned into a forward-looking approach to future fusion applications.

During the ITER negotiations, the U.S. domestic program has continued to support the domestic technical preparations for the ITER project and has begun to plan for the operation of ITER. These activities are being promoted and coordinated through the U.S. Burning Plasma Organization (USBPO) established in 2005 for this purpose. FES appointed the Director of USBPO in May 2005 to lead this effort.

The Energy Policy Act requires development of a plan by DOE for the participation of U.S. scientists in ITER that includes a U.S. research agenda, methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power, and a description of how work at the ITER will relate to other elements of the U.S. fusion program. The Act requires that this plan be developed in consultation with the Fusion Energy Sciences Advisory Committee (FESAC), and reviewed by the National Academy of Sciences.

In FY 2006, DOE initiated steps to develop a plan for the participation of U.S. scientists in ITER. FES asked the USBPO to coordinate and facilitate a coherent burning plasma related work program and ITER supporting research. The USBPO organized a national workshop at ORNL on December 7–9, 2005, to review the developments in the U.S. program on burning plasma related topics since the Snowmass 2002 study that formulated the technical basis for the U.S. to join ITER. The USBPO produced a ‘Plan for U.S. Scientific Participation in ITER’ with technical details in May 2006. As called for, the Plan was presented to FESAC for consultation. FESAC reviewed and agreed with the Plan in early June 2006. The Plan was forwarded to Congress on August 11, 2006, for a 60-day review, as required by the Energy Policy Act of 2005 Section 972(c)(4)(A)(i-iii), and it was concurrently submitted to the National Academy of Sciences for review.

Means and Strategies

The science and the technology of fusion have progressed to the point that the European Union, China, India, Japan, Korea, Russia, and the United States, seven parties representing over half of the world's population, have agreed to build ITER to explore the physics of a sustained burning plasma. In light of this action, many elements of the fusion program that are broadly applicable to burning plasmas are now being directed more specifically toward the needs of ITER. These elements represent areas of fusion research in which the United States has particular strengths relative to the rest of the world, such as theory, modeling, advanced tokamak physics, and fusion technology. Longer range technology activities have already been redirected to support preparations for ITER and associated experiments.

Scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad and conduct comparative studies to supplement the scientific understanding obtained from domestic facilities. 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 United States is collaborating with Korea and China on the design of diagnostics and control systems for their long-pulse, superconducting, advanced tokamaks (KSTAR and EAST). The strengthened relationships resulting from these international collaborations can foster scientific advancement and provide a valuable link with the 80% of the world's fusion research that is conducted outside the United States. The United States is an active participant in the International Tokamak Physics Activity (ITPA), which facilitates identification of high priority research for burning plasmas in general, and for ITER specifically, through workshops and assigned tasks. ITPA further identifies coordinated experiments on the international tokamak programs and coordinates implementation of these experiments through the International Energy Agency Implementing Agreements on tokamaks. In FY 2005, the United States established a community-based Burning Plasma Organization to stimulate and coordinate ITER-related research within the U.S. fusion program.

All research projects undergo regular peer review and merit evaluation based on SC-wide procedures and Federal regulations pertaining to extramural grant programs under 10 Code of Federal Regulations (CFR) 605. A similar and modified process is also followed for research proposals submitted by the laboratory programs and national collaborative facilities. All new projects are selected by peer review and merit evaluation. FES formally peer reviews the FES scientific facilities to assess the scientific output, collaborator satisfaction, the overall cost-effectiveness of each facility's operations, and the ability to deliver the most advanced scientific capability to the fusion community. Major facilities are reviewed by an independent peer review process on a five-year basis as part of the grant renewal process, or an analogous process for national laboratories. The three national fusion facilities (DIII-D at General Atomics, Alcator C-Mod at the Massachusetts Institute of Technology (MIT), and NSTX at PPPL) had such peer reviews in the April-June 2003 time frame. Checkpoint reviews after three years provide interim assessments of program quality. These checkpoint reviews for the three facilities were held in September 2006. Program Advisory Committees for the major facilities provide annual feedback on the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; collaborator satisfaction; facility staffing levels; research and development (R&D) activities to advance the facility; management of the facility; and long-range goals of the facility.

Facility upgrades and construction projects have a goal to stay within 10 percent, on average, of cost and schedule baselines for upgrades and fabrication of scientific facilities. In FES, fabrication of major research facilities has generally been on time and within budget. Major collaborative facilities have a goal to operate more than 90 percent, on average, of total planned annual operating time. FES's operation of major scientific facilities has ensured that a growing number of U.S. scientists have reliable access to those important facilities.

External factors that affect the level of performance include:

- changing mission needs as described by the DOE and SC mission statements and strategic plans;
- scientific opportunities as determined, in part, by proposal pressure and scientific workshops;
- results of external program reviews and international benchmarking activities of entire fields or sub fields, such as those performed by the National Academy of Sciences (NAS);
- unanticipated failures in critical components of scientific facilities that cannot be mitigated in a timely manner; and
- strategic and programmatic decisions made by non-SC funded domestic research activities and by major international research centers.

Validation and Verification

Progress against established plans is evaluated by periodic internal and external performance reviews. These reviews provide an opportunity to verify and validate performance. Monthly, quarterly, semiannual, and annual reviews consistent with specific program management plans are held to ensure technical progress, cost and schedule adherence, and responsiveness to program requirements.

Program Assessment Rating Tool (PART) Assessment

The Department has implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. FES has incorporated feedback from OMB and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the FES program a score of 82% overall which corresponds to a rating of "Moderately Effective." The assessment found that FES has developed a limited number of adequate performance measures which are continued for FY 2008. These measures have been incorporated into this budget request, FES grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of Management and Operating (M&O) contractors. To explain these complex scientific measures better, the Office of Science has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Fusion Energy Sciences Advisory Committee (FESAC) and also available on the website, will guide reviews, every three years by FESAC, of progress toward achieving the long-term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has provided FES with three recommendations to further improve performance:

- Develop strategic and implementation plans in response to multiple Congressional requirements.
- Implement the recommendations of expert review panels, especially two major National Academy of Sciences studies, as appropriate.
- Re-engage the advisory committee in a study of how the program could best evolve over the coming decade, including taking into account new and upgraded international facilities.

In response to previous OMB recommendations FES has:

- In accordance with the Energy Policy Act of 2005, prepared several reports which have been submitted to Congress in FY 2006: (1) A 'Plan for U.S. Scientific Participation in ITER'; (2) A report describing the management structure of the ITER and estimate of the cost of U.S. participation; and (3) A report describing how U.S. participation in ITER will be funded without a funding reduction in other SC programs.
- Formally charged the FESAC to assess progress toward the long term goals of the FES program.
- Tasked FESAC to prepare a report that identified and prioritized scientific issues and respective campaign strategies. The final report was completed in April 2005, and formed the basis of the September 2005 FES strategic plan.
- Established a Committee of Visitors (COV) process to provide outside expert validation of the program's merit-based review processes for impact on quality, relevance, and performance. The COV reports are available on the web at http://www.ofes.fusion.doe.gov/more_html/fesac.

During the past three years, COV committees have examined all elements of the FES program in the following order: (1) theory and computation, (2) innovative confinement concepts, high energy density physics, and general plasma science, and (3) tokamak research and enabling R&D. The three COV reports and the FES response to these reports are available at:
http://www.ofes.fusion.doe.gov/more_html/fesac/committeeofvisitors.pdf,
http://www.ofes.fusion.doe.gov/more_html/fesac/covlettertohazeltine.pdf,
http://www.ofes.fusion.doe.gov/more_html/fesac/cov_final.pdf, and
http://www.ofes.fusion.doe.gov/more_html/fesac/ofesresponseto2ndcov.pdf.

In general, these COVs have concluded that the FES-supported research programs are of high quality and that the biggest concern has been flat budgets for these programs. Further, the COVs have found that FES program managers are serious, conscientious, and dedicated, and are doing a good job managing their individual program elements.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov web site. Information concerning FES PART assessments and current follow up actions can be found by searching on "fusion energy sciences" at http://ExpectMore.gov.

Overview

Fusion science is a subfield of plasma science that deals primarily with the study of fundamental processes taking place in plasmas, or ionized gases, when the temperature and density approach the levels needed to allow the nuclei of two low-mass elements, e.g., hydrogen isotopes deuterium and tritium, to join together, or fuse. There are two leading methods of confining the fusion plasma—magnetic confinement, in which strong magnetic fields contain the charged plasma particles, and inertial confinement, in which laser or particle beams or x-rays (drivers) compress and heat the plasma (target) during very short pulses. Most of the world's fusion energy research effort, the United States included, is focused on the magnetic confinement approach. However, the National Nuclear Security Administration (NNSA) supports a robust program in inertial fusion for stockpile stewardship. By leveraging this large NNSA investment in facilities, FES can support a small research effort to study energy-relevant high energy density physics.

The FES program activities are designed to address the scientific and technology issues facing magnetic fusion and high energy density physics. The FESAC Priorities Panel has identified six scientific campaigns, or topical areas, to organize these scientific and technical issues in magnetic fusion and high energy density physics research. Four of these topical areas are in magnetic fusion: Macroscopic Plasma Physics, Multi-scale Transport Physics, Plasma-boundary Interfaces, and Waves and Energetic Particles. One topical area covers High Energy Density Physics, closely related to inertial fusion, and one topical area covers Fusion Engineering Science applicable to critical technologies important to practical fusion energy systems. The panel has identified 15 fundamental scientific questions, one to three for each topical area, in order to guide the key scientific research to be carried out in fusion energy science over the next ten years.

The six topical issues or scientific campaigns have been codified into three thrusts that characterize the program activities:

- Burning Plasmas, that will include our efforts in support of ITER;
- Fundamental Understanding, that includes high performance plasma experiments, theory and modeling, as well as general plasma science;
- Configuration Optimization, that includes innovative experiments on advanced tokamaks, and alternate concepts;

Progress in all of these thrust areas, in an integrated fashion, is required to achieve ultimate success.

How We Work

The primary FES role is the management of resources and technical 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 mutually beneficial 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 SC Director on complex scientific and technological issues that arise in the planning, implementation, and management of the FES program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research or related fields. The SC Director charges the Committee to provide advice and recommendations on various issues of concern to the FES program. The Committee conducts its business in public meetings, and submits reports with advice and recommendations to the Department.

A variety of other committees and groups provide input to program planning. For example, the National Research Council’s Plasma Science 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 effort. These high-level program reviews and peer reviews of research proposals provide a sound basis for developing program plans and priorities and allocating 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 comprised primarily of 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 host 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, thereby avoiding unnecessary duplication.

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 with 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 SC programs.

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 proposals 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. Grants typically extend for a three- to five-year period. The grants review process is governed by the already established SC Merit Review System. DOE national laboratories submit annual FWPs for funding of both new and ongoing activities. These are subject to peer review according to procedures patterned after those in 10 CFR Part 605, which governs 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 nominal five-year renewal dates. External peer reviews of laboratory programs are carried out on a periodic basis.

Another review mechanism, described previously in the PART Assessment section, involves charging FESAC to establish a Committee of Visitors (COV) to review program management practices of selected elements of the FES program each year, such that the entire program is reviewed every three to four years. In May 2006, the third COV completed its review of the research portfolio and peer review process for the FES Tokamak Research and Enabling R&D programs. This committee agreed with the recommendations of earlier COVs, and concluded that there was much evidence that the FES program managers have already implemented many of the recommendations of earlier COVs and were working to make further improvements in programs and processes. However, the committee noted that further work was needed to make the content of the review folders complete and consistent across the programs. The committee also developed the following new recommendations:

- statistics on the award process would be helpful
- the review sheet used for program renewals should explicitly include a review of progress
- some form of the proposal score should be communicated to the Principal Investigator (PI) in addition to reviewer comments
- the reviewer pool size should be increased
- the Junior Faculty Award program should be eligible to those outside of basic plasma science

These recommendations are being implemented for proposals requesting funds in FY 2007 and beyond.

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 Director in the field and other involved staff from both the Department and the performers.

MIE/Project Management

FES will continue to comply with the Department's project management regulations and will continue to utilize the oversight functions of the Department and the U.S. ITER Project Office at Oak Ridge National Laboratory in order to ensure that the U.S. investment in ITER is optimized and protected. This will be accomplished through compliance with DOE Order 413.3A, regular SC Office of Project Assessment "Lehman" Reviews, International ITER Reviews, and the overall coordination and management activities among FES, the U.S. ITER Project Office, and the ITER Organization.

As was done for the National Compact Stellarator Experiment, another FES Major Item of Equipment project, the U.S. ITER Project Office will develop a performance baseline, and FES will track these performance baselines on a regular basis. The target for ITER is the same as for other projects: cost-weighted mean percent variance from established cost and schedule baselines kept to less than 10%.

Now that the ITER Agreement has been signed and the ITER Organization is operating under provisional application (until entry into force in 2007), the Interim ITER Council will be providing such management controls and safeguards, as described in the ITER Agreement Article 6—Council. The U.S. and the other ITER parties have representation on the Council. In addition, Article 17—Financial Audit and Article 18—Management Assessment provide provisions for management controls and safeguards. For instance, Article 18 states that "Every two years, the Council shall appoint a Management Assessor who shall assess the management of the activities of the ITER Organization. The scope of the assessment shall be decided by the Council." In the event that a Party should fail to deliver a key component or system, the Common Understanding on Project Resource Management and Article 26—Withdrawal outlines the steps to be followed.

Planning and Priority Setting

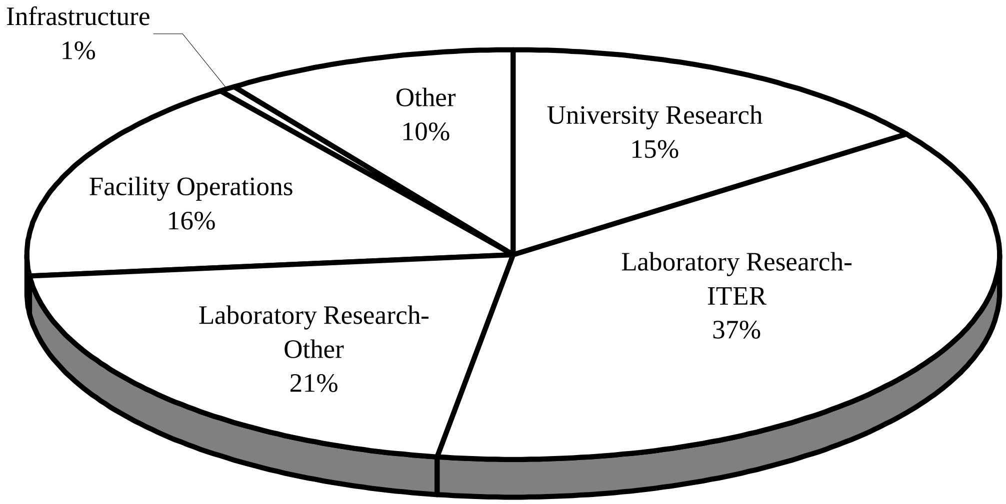
The FESAC carries out an invaluable role in the fusion program by identifying critical scientific issues and providing advice on intermediate and long-term goals to address these issues. As described above, FESAC has recently assisted the Department and the fusion community in establishing priorities for the fusion program, including strategies to integrate U.S. activities in ITER into the overall U.S. domestic fusion program.

A variety of sources of information and advice, as noted above, are integrated with peer reviews of research proposals. These, 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 components: Science, Facility Operations, and Enabling R&D. Research efforts are distributed across universities, laboratories, and private sector institutions. There are three major facilities located at: a national laboratory (Princeton Plasma Physics Laboratory [PPPL]); a private sector institution (General Atomics [GA]); and a university (MIT). In addition, there are several smaller experimental facilities located at other universities and labs. Technology supports and improves the technical capabilities for ongoing experiments and provides limited long-term development for future fusion power requirements.

Fusion Energy Sciences Budget Allocation
FY 2008



Research

The DOE Fusion Energy Sciences program funds research activities involving over 1,100 researchers and students at 65 academic and private sector institutions located in 30 states and at 11 DOE and Federal laboratories in eight 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. 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 science user facility at the University of California, Los Angeles (UCLA) that is jointly funded by DOE and the National Science Foundation (NSF). There are 5 universities with significant groups of theorists and modelers. About 40 Ph.D. degrees in fusion-related plasma science and engineering are awarded each year. Over the past three decades, many of these graduates have gone into the industrial sector and taken 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 peer reviewed proposals submitted in response to announcements of opportunity and available funding are competitively awarded according to the guidelines published in 10 CFR Part 605. Support for basic plasma physics is carried out mostly through the NSF/DOE Partnership in Basic Plasma Science and Engineering.

In addition, the FES Junior Faculty program supports tenure track university faculty on a competitive basis; research in fusion and plasma science is included in this program.

- **National Laboratory and Private Sector Research**

  FES 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 Laboratory, Argonne National Laboratory, Pacific Northwest 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.

Significant Program Shifts

The FY 2008 request is $427,850,000, 34.1% over the FY 2007 request. The FY 2008 request continues the redirection of the fusion program to prepare for and participate in the ITER project. The most significant increase from FY 2007 to FY 2008 is $100,000,000 for ITER. The increase of $8,900,000 for the remainder of the program generally supports activities at the same level of effort as FY 2007.

ITER

- **International Accomplishments:**

  Multilateral ITER negotiations continued in FY 2006. Significant advances during the negotiations included the selection of Cadarache, France as the host site for ITER, designation and approval of the Director General and Principal Deputy Director General, approval and invitation for India to join the ITER negotiations as a full non-host participant, agreement on the final allocations of "in-kind" hardware among the parties, and establishment of a Central Reserve for the international ITER Organization. As signified on May 24, 2006, by the initialing of the ITER Agreement by the seven parties, the comprehensive process to finalize the draft ITER Agreement and supporting documentation was completed. The steps following the Ministerial-level signing of the Agreement held on November 21, 2006, include ratification or formal acceptance of the Agreement by mid-2007 and entry into force and formal establishment of the ITER Organization by late 2007.

- **U.S. ITER Project Accomplishments:**

  The U.S. ITER Project Office (USIPO), serving as the U.S. domestic agency for the ITER Project, is responsible for the management of the U.S. contributions of hardware, personnel, cash, and contingency. Since the establishment of the Project Office in July 2004, the following accomplishments have been made:

  - preliminary cost and schedule ranges have been prepared, reviewed by SC, and revised to reflect resolution of uncertainties associated with the ITER Project;

- the Deputy Secretary of Energy approved Critical Decision 0, Approve Mission Need, for ITER as called for in DOE Order 413.3A;
- project management documentation required by DOE Order 413.3A is being prepared for the U.S. Contributions to ITER MIE project; and
- appointments of key management positions within the USIPO are now complete.

In FY 2006, and in accordance with DOE Order 413.3A, the FES program and the USIPO have been preparing for Critical Decision 1 (CD-1), Approve Alternative Selection and Cost Range, in late FY 2007–early FY 2008 and Critical Decision 2b (CD-2b), Approve Performance Baseline, in late FY 2008. In order to accommodate the necessary U.S. long-lead procurements in FY 2008, CD-2a/3a will be performed in conjunction with CD-1. It is important that the schedule for the Critical Decision milestones is consistent with the international ITER Project schedule, and that the schedule benefits from activities of the International ITER Project such as the initial design review to be conducted by the Director General and Principal Deputy Director General beginning in early 2007. The schedule for Critical Decision 2b is dependent on the ability of the international ITER Organization to finalize the design and schedule for the ITER Project—both of which affect the establishment of the performance baseline of the U.S. Contributions to ITER MIE project.

The overall Total Project Cost of $1,122,000,000 for the U.S. Contributions to ITER project is maintained.

In FY 2008, funding for the U.S. Contributions to ITER Major Item of Equipment (MIE) project is identified as Total Estimated Cost (TEC) in the Facility Operations subprogram and Other Project Costs (OPC) in the Enabling R&D subprogram. The TEC funding provides for the U.S. “in-kind” equipment contributions, U.S. personnel to work at the ITER site, cash for the U.S. share of common expenses such as infrastructure, hardware assembly and installation, and contingency for the ITER Organization. The OPC funding is provided for R&D in support of equipment—mainly magnets, first wall/shield modules, tritium processing, fueling and pumping, heating systems, and diagnostics, which would be provided by the U.S. to ITER. The results of this R&D are applicable to ITER and other burning plasma experiments. In addition, there is related support, not part of the OPC, for both the ITER physics basis and the preparations for science and technology research to be conducted using ITER. This support comes from a broad spectrum of science and technology activities within the FES program such as experimental research from existing facilities, as well as the fusion plasma theory and computation activities, and is not part of the MIE project.

The annual Total Project Cost (TPC) profile for FY 2006 through FY 2014 is provided below. The profile and TPC could change further in the future if increases in escalation and/or fluctuations in the currency exchange rates occur. The profile is preliminary until the Director General and the ITER Organization have achieved a standard mode of operation, and the baseline scope, cost, and schedule for the MIE project (CD-2b) are established.

U.S. Contributions to ITER MIE Project
Annual Profile[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Costs	Total Project Cost
2006	15,866	3,449	19,315
2007	37,000	23,000	60,000
2008	149,500	10,500	160,000
2009	208,500	6,000	214,500
2010	208,500	821	209,321
2011	181,964	—	181,964
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,078,230	43,770	1,122,000

Estimated TEC, OPC, and TPC

The table below reflects the results of the fall 2005 negotiations; i.e., India joined as an equal, non-host partner, cost sharing among the seven parties and the revised allocation of hardware contributions were finalized, and additional contingency was incorporated into the estimate. The shift in OPC and TEC funding, namely an increase in the TEC and decrease in the OPC, was made to be more consistent with DOE Order 413.3A principles and because less R&D is needed in the outyears. The OPC provides for R&D activities in support of the design; contingency is not provided for R&D. The Total Project Cost (TPC) remains $1,122,000,000. The TPC is based on project completion in 2014. The international ITER Organization recently announced a schedule indicating a first plasma in 2016. The international and domestic project schedule will be more firm at CD-2b, and the estimate remains preliminary until the baseline is established at CD-2b.

[a] Mission Need (CD-0) was approved in July 2005 with a preliminary TPC of $1.122 billion (the OMB cap). The funding profile is also preliminary and incorporates key results of the December 2005 negotiations. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The baseline TPC, including the funding profile, will be established at CD-2b planned for late FY 2008. The FY 2008 Budget Request is for engineering design and long-lead procurements only. Engineering design may include limited fabrication and testing of design concepts.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
U.S. Contributions to ITER Project		
Total Estimated Cost		
a. Procurement of U.S. in-kind equipment (non-host contribution to ITER)	487,140	573,800
b. Design of US in-kind equipment	58,800	—
c. Installation of U.S. in-kind equipment	69,350	71,900
d. Operation of U.S. ITER Project Office including management, QA, procurement, etc.	112,280	123,600
e. Assignment of U.S. scientists and engineers to ITER Org (non-host contribution to ITER)	22,090	87,300
f. Contribution of funds for support personnel at ITER Org (non-host contribution to ITER)	72,640	36,200
Subtotal	822,300	892,900
Contingency for Items a thru d above[a]	194,680	—
International ITER Organization Reserve[b]	61,250	—
Total Contingency (Current 31%, Previous 16%)	255,930	145,200
Total Estimated Cost (TEC)	1,078,230	1,038,000
Other Project Costs		
Other Project Costs – R&D for above tasks	43,770	68,000
Other Project Costs Contingency (Current 0%, Previous 24%)[c]	—	16,000
Total Other Project Costs (OPC)	43,770	84,000
Total Project Cost (TPC)	1,122,000	1,122,000

Related Annual Funding Requirements

The current estimate in the table below incorporates the results of the fall 2005 negotiations; i.e., agreement was reached on cost sharing during operations, deactivation and decommissioning. Specifically, it considers the procedure for converting currencies into Euros and the 20-year period of annual contributions to the decommissioning fund in conjunction with ITER operations.

[a] Contingency is provided for fabrication, design and installation of U.S. in-kind equipment.
[b] If contingency is needed for personnel and/or cash, such contingency would be covered by the U.S. contribution to the Central Reserve.
[c] Contingency is not provided for OPC activities.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
FY 2015–FY 2034[a]		
U.S. share of annual facility operating costs including commissioning, maintenance, repair, utilities, power, fuel, improvements, and annual contribution to decommissioning fund for the period 2015 to 2034. Estimate is in year 2015 dollars.	56,900	55,700
FY 2035–FY 2039		
U.S. share of the annual cost of deactivation of ITER facility for the period 2035–2039. Estimate is in year 2037 dollars.	18,200	17,700

The Total Project Cost for the U.S. Contributions to ITER MIE project is $1,122,000,000, consisting of TEC funding for the fabrication of the equipment including contingency, provision of personnel, the U.S. share of cash for common project expenses at the ITER site, and contingency for the ITER Organization, and the OPC funding for R&D activities supporting the TEC-funded procurements. This MIE is augmented by the technical output from a significant portion of the FES research program. The U.S. is a major participant in the International Tokamak Physics Activity (ITPA), which delineates high-priority physics needs for ITER and assists their implementation through collaborative experiments among the major international tokamaks, and analysis and interpretation of experiments for extrapolation to ITER. Virtually the entire FES program provides related contributions to such ITER-relevant research, not part of the TEC, OPC, and TPC, and prepares the U.S. for effective participation in ITER when it starts operations.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC program offices with the goal of achieving breakthrough scientific advances through computer simulation that are impossible using theoretical or laboratory studies alone. By exploiting the exponential advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-disciplinary collaboration among scientists, 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 SciDAC 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, and astrophysics.

During the past year, multidisciplinary teams of computational plasma physicists, applied mathematicians, and computer scientists continued work on three fundamental SciDAC research projects in the areas of macroscopic stability, electromagnetic wave-plasma interaction, and simulation of turbulent transport of energy and particles. During the preceding three years, these teams achieved significant advances in the simulation of mode conversion of radio frequency waves in tokamak plasmas, modeling of edge instabilities with realistic plasma parameters, and understanding turbulent transport as a function of plasma size in tokamaks. In early FY 2006, the FES program and the Advanced Scientific Computing Research (ASCR) program completed a competitive peer review process and funded two fusion simulation prototype centers—one on integrated simulation of tokamak edge plasmas, and one on integrated simulation of wave-plasma interaction and macroscopic stability.

[a] FY 2015 is the estimated date for start of operations based on the current international ITER schedule. This is one year later than was stated in the FY 2007 Budget request.

Scientific Facilities Utilization

The FES request includes funds to operate and use major fusion physics collaborative science facilities. The Department's three major fusion 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 (NSTX) at the Princeton Plasma Physics Laboratory.

The funding requested will provide research time for about 500 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 hours of operation at all of the major fusion facilities is shown in the following table.

	FY 2006	FY 2007	FY 2008
Optimal hours[a]	2,800	2,800	2,800
Planned hours	1,168	1,440	1,560
Achieved Hours	1,472[b]	N/A	N/A
Hours operated as percent of planned hours	126%	N/A	N/A

In addition to the operation of the major fusion facilities, the National Compact Stellarator Experiment (NCSX) MIE project at PPPL is supported. Milestones for this project are shown in the following table.

FY 2006	FY 2007	FY 2008
Complete fabrication of a vacuum vessel subassembly and two modular coils.	Complete winding of one half of the modular coils.	Complete winding of all of the modular coils.

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 masters and doctoral degrees, 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 2006, the FES program supported 461 graduate students and post-doctoral investigators. Of these, approximately 65 students conducted research at DIII-D, Alcator C-Mod, and NSTX. 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.

[a] This consists of 40 hours per week for DIII-D and NSTX and 32 hours per week for C-Mod.
[b] A refund of prior year tax payments allowed DIII-D to schedule 200 hours over the total supported by the FY 2006 appropriation. Excluding this additional operating time the percentage would be 109%.

Data on the workforce for the FES program are shown in the table below. The numbers for Permanent PhD's, Postdoctoral Associates, and Graduate Students include personnel at universities, national laboratories, and industry.

	FY 2006	FY 2007 estimate	FY 2008 estimate
# University Grants	236	211	260
# Permanent PhD's	707	718	775
# Postdoctoral Associates	110	112	120
# Graduate Students	351	356	385
# PhD's awarded	33	33	36

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to these projects funded within SC. Beginning in FY 2007, the EIR business line will be financed via the Working Capital Fund to achieve parity on how EIRs are funded and to standardize the administration of these critical activities.

Joint Program in High Energy Density Laboratory Plasmas

The National Nuclear Security Administration (NNSA) and SC are establishing[a] a joint program in High Energy Density Laboratory Plasmas (HEDLP), a major sub-area within the discipline of high energy density physics (HEDP). The joint program will establish appropriate HEDLP peer review infrastructure, including solicitations, user groups, and user facility policies, in order to effectively steward HEDLP within DOE while maintaining the interdisciplinary nature of this area of science. HEDLP joint program stewardship supports the Department's programmatic goals in inertial confinement fusion science, including exploring energy-related topics, research into extreme states of matter, and stockpile stewardship. Other agencies may join the program in the future as dictated by agency needs and priorities. Funding for the program is shown below.

	(dollars in thousands)		
	FY 2006[b]	FY 2007	FY 2008
Fusion Energy Sciences	15,470	11,949	12,281
NNSA-Office of Defense Programs	12,086	10,000	12,356
Total, High Energy Density Laboratory Plasma Joint Program	27,556	21,949	24,637

The joint program in HEDLP will provide for FES participation in and coordination with the NNSA's Stewardship Science Academic Alliance Program (SSAA) and the National Laser User Facility Program. The joint program will minimize research duplication, increase HEDLP research at NNSA facilities, and provide for a SC-style competitive and peer reviewed grant process. Further details on the FES contributions to the joint program are contained in the FES Alternative Concept High Energy

[a] Establishment of the HEDLP joint program is expected by spring of 2007.
[b] Prior year funds for HEDLP-related activities are included for reference.

Density Physics budget narrative. Similarly, further details on the NNSA contributions to the joint program can be found in the NNSA's budget narrative on Inertial Confinement Fusion (ICF) and High Yield and Focused Stockpile Research campaigns, which include individual investigator (grants) and research centers activities (cooperative agreements) in HEDP funded under the NNSA Stewardship Science Academic Alliances Program (SSAA), and also NNSA user programs such as the National Laser User Facility Program.

In FY 2008, the joint program will issue a combined solicitation for FES university activities and existing NNSA research centers that supports academic research in this area. Separate companion solicitations for the national laboratories will be considered by FES from time to time. The joint program will be assessed frequently to determine its success in advancing HEDLP.

Science

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Science			
Tokamak Experimental Research	45,701	45,838	49,258
Alternative Concept Experimental Research	59,594	56,302	56,711
Theory	24,947	23,900	24,552
SciDAC	4,220	6,970	7,160
General Plasma Science	14,180	13,941	14,655
SBIR/STTR	—	7,262	7,193
Total, Science	148,642	154,213	159,529

Description

The Science subprogram promotes 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, funded by the FES program, 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 mass of the resultant plasma to escape during the time when significant fusion reactions occur. The target physics and major experiments in inertial fusion are funded by NNSA. The scientific feasibility of inertial fusion is underpinned by the pertinent subfields of high energy density physics. The Science subprogram supports exploratory research to combine the favorable features of, and the knowledge gained from, magnetic confinement and/or high energy density physics, both for steady-state and pulsed approaches, in new, innovative fusion concepts. There has been great progress in plasma science during the past three decades, in both magnetic confinement and high energy density physics, and today the world is at the threshold of a major advance in fusion energy development—the study of burning plasmas, in which the self-heating from fusion reactions dominates the plasma behavior. Such a burning plasma will be demonstrated in ITER for the first time. The magnetic fusion program is being organized to emphasize investigation of key physics issues for burning plasmas, in preparation for the ITER experiments.

Benefits

The Science subprogram provides the fundamental understanding of plasma science needed to address and resolve critical scientific issues related to fusion burning plasmas. This work is carried out on major fusion facilities, in small experiments, and supported by extensive theoretical and computational research. The Science subprogram also explores and develops diagnostic techniques and innovative concepts that optimize and improve our approach to creating fusion burning plasmas, thereby seeking to minimize the programmatic risks and costs in the development of a fusion energy source. Finally, this subprogram provides training for graduate students and postdoctoral associates, thus developing the national workforce needed to advance plasma and fusion science.

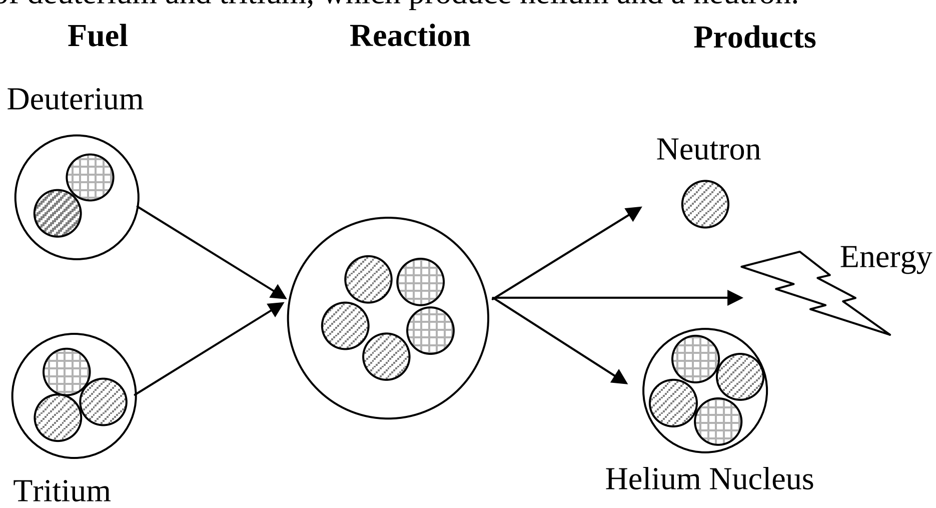
Supporting Information

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 ten years the Science subprogram will continue to advance our understanding of plasmas through an integrated program of experiments, theory, and simulation as outlined in the Integrated Program Planning Activity for the FES Program prepared for FES and reviewed by the FESAC. This integrated research program focuses on well-defined plasma scientific issues including turbulence, transport, macroscopic stability, wave particle interactions, multiphase interfaces, hydrodynamic stability, implosion dynamics, fast ignition, 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. This integrated research program also will benefit from ignition experiments performed at 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, a NSF/DOE partnership in plasma physics and engineering, and the Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. The ongoing Fusion Science Centers 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, radioactive 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 industrial processing, national security, space propulsion, and astrophysics.

Fusion science, a major sub-field of plasma science, is focused primarily on describing the fundamental processes taking place in plasmas, or ionized gases, in which peak temperatures are greater than 100 million degrees Celsius, and densities are high enough that light nuclei collide and fuse together, releasing energy and producing heavier nuclei. The reaction most readily achieved in laboratory plasmas is the fusion of deuterium and tritium, which produce helium 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, self-organization, 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 source.

For High Energy Density Physics, the major fusion science issues are: (1) high energy density physics that describes intense laser-plasma and beam-plasma interactions; (2) implosion dynamics and stability; (3) target physics and the science of target fabrication; and (4) non-neutral plasmas, as is seen in the formation, transport, and focusing of intense heavy ion beams.

FY 2006 Science Accomplishments

- **Rotational Stabilization of Instabilities on DIII-D**

  In the quest to stably confine high-pressure plasmas for fusion power, it has long been known that rapid spinning of the plasma due to neutral beam injection stabilizes resistive wall modes, instabilities in the outer region of the plasma. Unfortunately, such rapid rotation will not occur in fusion power plants, where the plasma will be self-heated by the alpha particles produced by the fusion reactions. However, recent research on the DIII-D national fusion facility now indicates that the rotation speed needed to stabilize these modes is lower than previously thought. This research has important implications for ITER, since ITER is expected to have low plasma rotation speed. This favorable result was made possible by the reorientation of one of the neutral beam injectors on DIII-D during a year-long shutdown for maintenance and upgrades.

- **Microwaves Drive a Million Amperes of Plasma Current in Alcator C-Mod**

  Replacing the current driven by the transformer in tokamaks is essential for continuous operation, and an important issue confronting the development of tokamaks into practical fusion power plants. Using current driven by radio-frequency (RF) waves in Alcator C-Mod, nearly 100% of up to 1 million Amperes of current originally driven by the transformer has been replaced using 800 to 900 kilowatts (kW) of RF power, for pulse lengths approaching one current profile rearrangement time. The results are in line with theoretical and numerical predictions, and imply that with increased RF power and pulse length, at higher densities and temperatures, plasmas in Alcator C-Mod could be entirely sustained without the aid of a transformer under conditions approaching those required for near steady-state operation in ITER.

- **High-Resolution Nonlinear Simulations of Edge Localized Modes**

  Predicting the behavior and optimizing the confinement in a tokamak burning plasma device such as ITER requires improved simulations of the entire plasma region, particularly the plasma edge. The steep gradients present at the edge give rise to a class of quasi-periodic nonlinear oscillations known as Edge Localized Modes or ELMs. The simulation of the nonlinear physics of these events is very challenging due to the fine-scale structures that develop and influence the ELM frequency and magnitude. This year, the large nonlinear extended MHD codes being developed in the U.S.—NIMROD and M3D—have been able to substantially increase the realism of their simulations by increasing the resolution of their models, allowing the inclusion and study of physical processes previously neglected—most notably sheared plasma rotation. These high resolution simulations, including sheared plasma flow, help to illuminate the important plasma properties that determine different ELM behavior. This knowledge is key to begin developing control techniques to modify ELM behavior, leading to higher performance in ITER.

- **Ion Heating in the Madison Symmetric Torus**

In the Madison Symmetric Torus (MST), a large reversed field pinch experiment at the University of Wisconsin-Madison, plasmas have recently been produced in which ions, as well as electrons, attain temperatures of about 10 million degrees. The ions are heated by a sudden magnetic reconnection event, during which more than 10 megawatts (MW) of power is transferred from the magnetic field to the ions. The event can now be timed such that it occurs immediately before the period of improved confinement, which retains the added ion heat. In conventional methods of heating plasmas in magnetic fusion, electrons are first heated by microwave sources. The electrons then transferred the energy to the ions by collisions. Losses occur in the process and limit the efficiency of such heating techniques. MST scientists are studying the field reconnection phenomenon as a potential technique for efficient heating of the ions directly without having to go through the cycle of heating the electrons.

- **Novel Method for Generating Plasma Current in the National Spherical Torus Experiment**

  Coaxial Helicity Injection (CHI) has previously been used to generate toroidal currents in small fusion experiments, such as the Helicity Injected Tokamak (HIT-II) at the University of Washington. Recent results from the National Spherical Torus Experiment (NSTX) demonstrate that this technique for generating toroidal current in a plasma works well in larger facilities too. CHI was used to generate a plasma current of 160,000 Amperes, a world record for non-inductive closed-flux current generation. This result is important for future spherical torus fusion experiments, since there will be little room for a solenoid primary winding in such experiments.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Tokamak Experimental Research	**45,701**	**45,838**	**49,258**

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 coordinated programs on the two major U.S. tokamak facilities, DIII-D at General Atomics and Alcator C-Mod at MIT. Both DIII-D and Alcator C-Mod are operated as national collaborative science 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 (ITPA), both DIII-D and Alcator C-Mod continue to increase their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

In FY 2008, U.S. tokamak research will continue to focus on supporting ITER. DIII-D will have the opportunity to further exploit new experimental flexibilities acquired through hardware improvements completed in FY 2005 and FY 2006. C-Mod will pursue a program with high magnetic field and high power densities incident on ITER-candidate materials, while utilizing recent hardware upgrades to improve control of various plasma parameters. In international collaborations, the scope of joint ITPA experiments will be enhanced to accommodate new experiments in support of ITER. These activities will enhance the understanding of key ITER physics issues, including plasma stability control,

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

disruption mitigation, wave-particle interaction, energy and particle transport, and development of improved plasma discharges for burning plasma studies on ITER.

There will also be some preparatory work for enhanced collaboration on new superconducting tokamaks in Korea and China to investigate steady state physics and technology 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. They do this by controlling the distribution of current in the plasma with electromagnetic wave current drive. The interface between the plasma edge and the material walls of the confinement vessel is managed 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.

	FY 2006	FY 2007	FY 2008
▪ **DIII-D Research**	**24,274**	**24,300**	**25,264**

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 the properties of high temperature plasma. It also has unique capabilities to shape the plasma and provide feedback control of error fields that, in turn, affect particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a “magnetic divertor” to control 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 primary goal of the DIII-D program is to advance the understanding of the science of fusion plasmas in all four key Magnetic Fusion Energy (MFE) fusion topical science areas of energy transport, stability, plasma-wave interactions, and boundary physics, and to explore various crosscutting issues that integrate across topical areas to enable the success of ITER and achieve a burning plasma. In the past few years, the investigation of ITER relevant discharge scenarios, including the development of advanced scenarios, has gained emphasis in the DIII-D experimental program.

In FY 2008, the DIII-D program will continue to exploit the new experimental flexibility acquired in the past two years. DIII-D experiments will focus on providing solutions to key ITER issues and developing the control tools and the science basis for high performance, steady state tokamak operation. High priority will be given to building a firm physics basis for key ITER design decisions in the areas of resistive wall mode stabilization in low rotation plasmas, neoclassical tearing mode stabilization utilizing modulated electron cyclotron current drive, the suppression of edge localized modes with resonant magnetic perturbations, and disruption detection and mitigation techniques. The DIII-D program will also be able to accommodate a reasonable number of ITPA joint experiments with the international community.

	FY 2006	FY 2007	FY 2008
▪ **Alcator C-Mod Research**	**8,490**	**8,890**	**9,133**

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 the only tokamak in the world operating at and above the ITER design magnetic field and plasma densities, and it produces the highest pressure tokamak plasma in the world, approaching pressures expected in ITER. It is also

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

unique in the use of all-metal 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 ITER. The facility has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks, all of which are important integrating issues for burning plasmas.

In FY 2008, C-Mod will conduct a strong research program primarily in support of ITER. Experiments will test the performance of the tungsten divertor tiles, an ITER-candidate material, under near-ITER-level incident power densities. ITER quasi-steady-state operating scenarios using lower hybrid and ion cyclotron radio frequency waves will be developed. A newly installed cryopump will greatly improve plasma density control, enabling access and investigation into new advanced tokamak regimes. Plasma rotation in the absence of significant momentum injection, also very important to ITER stability, will be further explored.

Other ITER-relevant topics that the C-Mod team will focus on in FY 2008 include plasma surface interaction with all-metal walls, measuring the effects of and mitigating disruptions in the plasma, understanding the physics of the plasma edge in the presence of large heat flows, controlling the current density profile for better stability, and helping to build international cross-machine databases using dimensionless parameter techniques. C-Mod will participate in many joint experiments organized by the ITPA involving all seven ITER parties.

▪ **International**	**4,951**	**5,064**	**5,202**

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 FES program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. This allows U.S. scientists to have access to the unique capabilities of facilities that exist abroad. These include the world’s highest performance tokamaks (JET in England and JT-60U 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 Korea on KSTAR on the design of plasma diagnostics, control systems, and with China for physics operations on the new long-pulse, superconducting, advanced tokamak EAST. The U.S. collaboration on EAST was instrumental in EAST achieving its first plasma on September 26, 2006. These collaborations provide a valuable link with the 80% of the world’s fusion research that is supported and conducted outside the U.S.

The increase in FY 2008 from the FY 2007 level will allow continued U.S. participation in high priority research activities in support of ITER. These include joint ITPA experiments on the large tokamaks JET and JT-60U, some joint experiments on medium sized tokamaks such as TEXTOR and ASDEX-UG in Germany, and other joint ITER-relevant experiments in the areas of plasma wall interactions, plasma instabilities, and first wall design considerations for ITER. In addition, the level of U.S. participation in steady-state physics and technology issues in Tore Supra, KSTAR, and EAST will be maintained. These activities will prepare U.S. scientists for participation in burning plasma experiments on ITER.

▪ **Diagnostics**	**3,763**	**3,854**	**3,959**

Support of the development of unique measurement capabilities (diagnostic instruments) will continue. Diagnostic instruments serve two important functions: (1) to provide a link between

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

theory/computation and experiments for an understanding of the complex behavior of the plasma in fusion research devices; and (2) to provide sensory tools for feedback control of plasma properties in order to enhance device operation. In FY 2008, research will include the development of diagnostics for fundamental plasma parameter measurements, state-of-the-art measurement techniques, and R&D for ITER-relevant diagnostic systems. Diagnostic systems will be installed and operated on current experiments in the United States and on non-U.S. fusion devices through collaborative programs.

The key areas of diagnostic development research will be those identified in the FESAC Report "Scientific Challenges, Opportunities and Priorities for the U.S. Fusion Energy Sciences Program," April 2005: macroscopic plasma physics, multi-scale transport physics, plasma boundary interfaces, waves and energetic particles, and burning plasma physics.

A competitive peer review of the diagnostics development program will be conducted in FY 2007 for funding that begins in FY 2008.

▪ **Other**	**4,223**	**3,730**	**5,700**

Funding in this category supports educational activities such as research at historically black colleges and universities (HBCUs), graduate and postgraduate fellowships in fusion science and technology, and summer internships for undergraduates. In addition, there is funding for outreach efforts related to fusion science and enabling R&D and operational costs for the U.S. Burning Plasma Organization and FESAC.

Alternative Concept Experimental Research	**59,594**	**56,302**	**56,711**

This program element broadens the fusion program by exploring the science of confinement optimization in the extended fusion parameter space, with plasma densities spanning twelve orders of magnitude, seeking physics pathways to improve confinement, stability and reactor configurations. Through this scientific diversity, the program element adds strength and robustness to the overall fusion program, by lowering the overall programmatic risks in the quest for practical fusion power in the long term, for which economics and environmental factors are important. At present, three alternate concepts are being pursued at the larger-scale, proof-of-principle level. A number of concepts are being pursued at a concept-exploration level with smaller-scale experiments, as well as research in establishing a knowledge base for high energy density plasmas. The smaller scale experiments and the cutting-edge research have proven to be effective in attracting students and strongly contribute to fusion workforce development and the intellectual base of the fusion program. The research has also resulted in new ideas for the larger toroidal devices (i.e. ITER support). The diversity combined with the excellence of research make the U.S. program the world leader in innovative concepts.

▪ **National Spherical Torus Experiment (NSTX) Research**	**15,539**	**16,696**	**16,106**

NSTX is one of the world's two largest spherical torus confinement experiments; the MegaAmp spherical tokamak in England is the other. Spherical tori have a unique, nearly spherical plasma shape that complements the doughnut shaped tokamak and provides a test bed for the theory of toroidal magnetic confinement as the spherical limit is approached. Theory predicts that plasmas in a spherical torus will be stable even when high ratios of plasma-to-magnetic pressure and large self-driven current fractions exist simultaneously, provided there is a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that a spherical torus uses applied magnetic fields more efficiently than most other magnetic confinement systems and could,

	(dollars in thousands)	
FY 2006	FY 2007	FY 2008

therefore, be expected to lead to a more cost-effective fusion power system. An associated issue for spherical torus configurations is the challenge of starting and maintaining the 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, like all high beta plasmas, is characterized by high temperature, fast ions with a large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. In FY 2008, NSTX research will focus on topics that are important to ITER, as well as to the development of the spherical torus concept. Research on turbulence and transport will focus on measurements of poloidal rotation at low aspect ratio to validate theoretical work. Macroscopic stability studies will concentrate on the use of feedback stabilization and strong shaping to control pressure-limiting modes. Specific experimental campaigns will contribute to assessing the onset conditions and impact of an instability called a “tearing mode,” characterizing the effectiveness of feedback control of resistive wall modes, and investigating the effect of active feedback control of unstable modes on longer pulse, high performance plasmas. Boundary physics studies will emphasize studying the behavior of the edge/divertor plasma at low collisionality at ITER-level heat fluxes. Finally, integrated scenario investigations will center on non-inductive current ramp-up and sustainment of high performance plasmas.

	FY 2006	FY 2007	FY 2008
▪ **Experimental Plasma Research**	**21,389**	**19,990**	**20,638**

This element undertakes cutting-edge research to explore innovative, improved pathways to plasma confinement to produce practical fusion energy. The emphasis is on developing the fundamental understanding of the plasma science that underpins innovative fusion concepts. This element is a broad-based research activity, conducted in about 25 experiments and theory-support projects, involving approximately 30 principal investigators and co-principal investigators in 11 universities, 4 national laboratories and industry. Because of the small size of the experiments and the use of sophisticated technologies, the research provides excellent educational opportunities for students and postdoctoral associates, and helps to develop the next generation of fusion scientists. In order to foster a vigorous breeding ground for research, each project is competitively peer reviewed on a regular basis of three to five years, so that a portfolio of projects with high performance is maintained. This is an area of magnetic fusion research where the United States has a commanding lead over the rest of the world. Because of its innovative and cutting-edge nature, this research element incubates and engenders the future of our quest for fusion energy. It has strong appeal to young and talented undergraduates who desire to make a major impact on the quest for fusion energy, attracting them to graduate studies in fusion.

Research opportunities exist for exploiting the physics and engineering advantages offered by plasma self-organization, geometric variations, higher densities, higher magnetic fields, plasma rotation, shear-flow stabilization, electric fields, and pulsed modes of operation. The Plasma Science and Innovation Center at the University of Washington was established in FY 2005 to provide computational support to the program. Since the inception of the Innovative Confinement Concepts (ICC) program in the restructured fusion program in 1998, a number of small, concept-exploration-level experiments have been constructed, including experiments on spheromaks; field reversed configurations; magnetized target fusion; a levitated dipole; centrifugally confined magnetic mirrors; flow-stabilized z-pinch; and electrostatic confinement. Most of these experiments have entered the second, definitive cycle in the data collection process. The near-term goal of the program is twofold:

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

(1) to generate sufficient experimental data for elucidating the physics principles on which these concepts work in a definitive manner, and (2) to develop computer models for these concepts with a sufficient degree of physics fidelity. The achievement of these two objectives will either allow assessments of the path forward in the further advancements of these concepts or the termination of further development of a particular concept. The requested FY 2008 funding is required to sustain progress of the program towards these goals.

▪ **High Energy Density Physics**	**15,470**	**11,949**	**12,281**

The combination of high plasma density and high plasma temperature needed for inertial fusion produces plasmas with very high energy densities. Energy densities in excess of 100 billion joules per cubic meter are of interest to inertial fusion, and their study is an emerging field of physics called High Energy Density Physics (HEDP). Plasmas at these energy densities are characterized by having pressures exceeding a million atmospheres. In the laboratory, these high energy density conditions are produced typically through the use of high power lasers, ion beams, or convergence of high density plasma jets.

HEDP is an emerging field of science. Understanding the behavior of matter at high energy densities is identified by the National Academy of Sciences as one of the eleven scientific challenges for the 21st Century. The National Ignition Facility (NIF) is slated to become fully operational in FY 2009–FY 2010, with the first ignition experiment to be initiated around FY 2010. The focus of the FES program is to explore innovative approaches to HEDP and to position the research community to take advantage of the availability of NIF to pursue energy-relevant HEDP, maintaining our world leadership in this field. The research described below is planned in response to the 2007 report of the Interagency Task Force on High Energy Density Physics and in support of the joint program in High Energy Density Laboratory Plasma (HEDLP) between FES and the NNSA ICF program.

The requested funding in FY 2008 is required to sustain research in fast ignition, high Mach number plasma jets and the study of dense plasmas in ultrahigh magnetic fields. These are exciting new fields of HEDP that are attracting worldwide scientific attention. Research will continue on the relativistic physics of thermal transport in fast ignition. The development of the cryogenic targets for fast ignition will be postponed or slowed down. Modest efforts to explore experimental techniques to produce high Mach number, high density plasma jets in the laboratory, create plasmas in high magnetic fields, and study their application to HEDP are being pursued. Research on plasma jet development is expected to be poised to begin studying the merging of plasma jets to form high energy density plasmas. The research leverages and collaborates with NNSA's program efforts in non-defense areas of HEDP and makes use of NNSA's facilities at the University of Rochester, LLNL, and LANL. Collaboration will be extended to other Federal agencies as well, wherever appropriate, through an interagency process that is in progress.

The requested funding will also allow research to continue in heavy ion beam science. The research will develop the knowledge base on the highly successful technique of neutralized drift compression (NDCX-I) using a longitudinal velocity profile demonstrated during FY 2005 and FY 2006. This knowledge base will allow the development of the second generation of the neutralized drift compression experiment that would lay the technical basis for potentially developing an ion-driven HEDP facility for the study of warm dense matter. The requested funding will also allow research on electron cloud dynamics in the High Current Beam Transport Experiment (HCX).

	FY 2006	FY 2007	FY 2008
	(dollars in thousands)		
▪ **Madison Symmetrical Torus**	**6,445**	**6,970**	**6,970**

The goal of the Madison Symmetrical Torus (MST), at the University of Wisconsin-Madison, is to obtain a fundamental understanding of the physics of reversed field pinches (RFPs), particularly magnetic fluctuations and their macroscopic consequences, and to use this understanding to develop the RFP fusion configuration. The RFP is geometrically similar to a tokamak, but with a much weaker magnetic field that reverses direction near the edge of the plasma. Research in the RFP's self-organization properties has astrophysical applications and may lead to a more cost-effective fusion system. The plasma dynamics that limit the energy confinement, the ratio of plasma pressure to magnetic field pressure, and the sustainment of the plasma current in a RFP are being investigated in this experiment. MST is one of the four leading RFP experiments in the world, and is unique in that it pioneered the reduction of magnetic fluctuations by current density profile control. In recent years, this approach has led to a ten-fold increase in energy confinement time.

In FY 2008, MST plans to test electron Bernstein wave injection and complete construction of a lower hybrid wave antenna system that will more than double FY 2006 power levels. The research team will also complete construction of a fast Thomson scattering diagnostic system, continue construction of a programmable power supply to dramatically improve plasma control, and determine whether to pursue full current sustainment by oscillating field current drive. As an important thrust of its overall research program, MST will continue to explore the feasibility of a pulsed power plant scenario, which may prove to have significant advantages over a steady-state fusion power plant.

▪ **National Compact Stellarator Experiment Research**	**751**	**697**	**716**

This funding supports the research portion of the program to be executed with the National Compact Stellarator Experiment (NCSX) at PPPL, which involves participation and a leadership role within the National Compact Stellarator Program (NCSP). PPPL, ORNL, and LLNL are the participants in NCSX research that keep abreast of physics developments in domestic and international stellarator research, factoring those developments into planning of the NCSX experimental program, as well as preparation of long-lead-time physics analysis tools for NCSX application. These tools have a dual use: setting physics requirements for hardware upgrades and interpreting data from future NCSX experiments. Some long-lead hardware upgrades will be designed, such as plasma control, first wall, and diagnostic systems. The NCSX team will: (1) finalize preparations for the start of experimental operations in FY 2009, including requesting initial collaboration proposals; (2) prepare for experiments to elucidate key configuration characteristics by e-beam mapping, including the study of the effects of field perturbations such as coil leads and feeds, and fabrication errors; and (3) set requirements for key diagnostic and facility upgrades.

Theory	**24,947**	**23,900**	**24,552**

The Theory program provides the conceptual scientific underpinning for the FES program by supporting three of its thrust areas: burning plasmas, fundamental understanding and configuration optimization. Theory efforts meet the challenge of describing the complex multiphysics, multiscale, non-linear plasma systems at the most fundamental level and, in doing so, generate world-class science. These descriptions—ranging from analytic theory to highly sophisticated computer simulation codes—are used to interpret results from current experiments, plan new experiments in existing facilities, design future experimental facilities, and assess projections of their performance. The program focuses on both

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

tokamaks and alternate concepts. Work on tokamaks is aimed at developing a predictive understanding of advanced tokamak operating modes and burning plasmas—both of which are important to ITER—while the emphasis on alternate concepts is on understanding the fundamental processes determining equilibrium, stability, and confinement for each concept. The theory program also provides the basic physics needed in the FES program large-scale simulation efforts that are part of the Scientific Discovery through Advanced Computing (SciDAC) portfolio and, together with SciDAC, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and controlled.

The Theory program is a broad-based program with researchers located at six national and federal laboratories, over thirty universities, and several private companies. Institutional diversity is one of the strengths of the program, since theorists at different types of institutions play different but complementary roles in the program. Theorists in larger groups, located mainly at national laboratories and private industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring multidisciplinary teams. Those at universities tend to support smaller, innovative experiments or work on more fundamental problems in plasma physics while training the next generation of fusion plasma scientists.

SciDAC	**4,220**	**6,970**	**7,160**

Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing. Current projects are focused on the topics of microturbulence simulation, extended magnetohydrodynamics modeling, and simulation of electromagnetic wave-plasma interaction, which will provide a fundamental understanding of plasma science issues important to a burning plasma and lay the groundwork for a possible future fusion simulation project. New projects will continue to involve collaborations among physicists, applied mathematicians and computer scientists, advancing both the fusion energy science and computational modeling fields. In FY 2006, the FES program and the Advanced Scientific Computing Research program initiated two fusion simulation prototype centers to prepare for a possible fusion simulation project in the future, following a competitive peer review process. One center is focused on integrated simulation of the edge plasma in a tokamak, and the other is concerned with the control of large-scale instabilities with electromagnetic waves.

In FY 2008, these prototype centers, along with the three continuing SciDAC projects, will emphasize development of new computing techniques and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space, including plasma turbulence and transport, large scale instabilities and stability limits, boundary layer/edge plasma physics, and wave-plasma interaction. These problems were beyond the capability of the fastest computers in the past, but it is now becoming possible to make progress on problems that once seemed intractable. The objective of the FES 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 and fruitful collaboration on major international facilities.

General Plasma Science	**14,180**	**13,941**	**14,655**

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 that make

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

contributions in many basic and applied physics areas. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Fusion Science Centers, and the Plasma Physics Junior Faculty Development Program. The program will continue to fund proposals that have been peer reviewed. Funding will also continue for the Fusion Science Center program that was started in FY 2004 with approximately $2,390,000 each year in FY 2006 and FY 2007. These Centers perform fusion plasma science research in areas of such wide scope and complexity that it would not be feasible for individual investigators or small groups to make progress, and they strengthen the connection between the fusion research community and the broader scientific community. Basic plasma physics user facilities will be supported at both universities and laboratories, sharing costs with NSF where appropriate. FES will provide $1,666,000 toward operations and in-house research at the Basic Plasma Science Facility in FY 2008. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. The FES program will continue to share with NSF the cost of funding the multi-institutional plasma physics frontier science center started in FY 2003.

	FY 2006	FY 2007	FY 2008
SBIR/STTR	**—**	**7,262**	**7,193**

In FY 2006, $6,215,000 and $746,000 was transferred to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2007 and FY 2008 amounts are the estimated requirements for the continuation of these programs.

	FY 2006	FY 2007	FY 2008
Total, Science	**148,642**	**154,213**	**159,529**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Tokamak Experimental Research	
▪ **DIII-D Research**	
This increase will allow the DIII-D national research team to conduct research relevant to burning plasma issues and topics of interest to the ITER project in addition to maintaining the broad scientific scope of the program.	+964
▪ **Alcator C-Mod Research**	
The increase will maintain the C-Mod research team at current staffing levels.	+243
▪ **International**	
The increase will maintain and enhance the collaborative effort on international tokamaks, allowing U.S. scientists to participate in ongoing tokamak experiments in the European Union and Japan.	+138
▪ **Diagnostics**	
The increase will maintain the level of effort for developing new base-program and ITER-relevant diagnostics.	+105

	FY 2008 vs. FY 2007 ($000)
▪ **Other**	
The increase will restore funding to pre-FY 2007 levels for Historically Black Colleges and Universities, education outreach activities, and operation of the U.S. Burning Plasma Organization.	+1,970
Total, Tokamak Experimental Research	**+3,420**
Alternate Concept Experimental Research	
▪ **National Spherical Torus Experiment Research**	
The net decrease is the result of transferring $750,000 of equipment funds for diagnostic upgrades from the research budget to the facility operations budget. An increase of $160,000 will maintain the NSTX research team at current staffing levels.	-590
▪ **Experimental Plasma Research**	
The increase provides for the same level of effort and focus as FY 2007.	+648
▪ **High Energy Density Physics**	
The increase provides for the same level of effort and focus as FY 2007.	+332
▪ **National Compact Stellarator Experiment Research**	
The increase provides for the same level of effort and focus as FY 2007.	+19
Total, Alternative Concept Experimental Research	**+409**
Theory	
The increase provides for the same level of effort and focus as FY 2007.	+652
SciDAC	
The increase will support the same level of effort as FY 2007.	+190
General Plasma Science	
The increase will support high-quality grants funded under the NSF/DOE Partnership in Basic Plasma Science and Engineering, additional funding for a Junior Faculty grant, and additional research on the Basic Plasma Science Facility at UCLA.	+714
SBIR/STTR	
Support for SBIR/STTR is provided at the mandated level.	-69
Total Funding Change, Science	**+5,316**

Facility Operations

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Facility Operations			
DIII-D	30,780	32,362	34,405
Alcator C-Mod	13,032	13,941	14,322
NSTX	18,681	18,422	19,972
NCSX (MIE)	17,019	15,900	15,900
GPP/GPE/Other	3,538	3,930	2,905
ITER Preparations	5,294	—	—
U.S. Contributions to ITER (MIE TEC)	15,866	37,000	149,500
Total, Facility Operations	104,210	121,555	237,004

Description

The mission of the Facility Operations subprogram is to manage 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 collaborators. In addition, fabrication of new projects and upgrades of major fusion facilities will be accomplished in accordance with the highest standards and with minimum deviation from approved cost and schedule baselines.

Benefits

The Facility Operations subprogram operates the major facilities needed to carry out the scientific research program in a safe and reliable manner. This subprogram ensures that the facilities meet their annual targets for operating weeks and that they have state of the art, flexible systems for heating, fueling, and plasma control required to optimize plasma performance for the experimental programs. Further, this subprogram fabricates and installs the diagnostics that maximize the scientific productivity of the experiments. Finally, this subprogram provides for the fabrication of new facilities such as NCSX, and for participation in the international collaboration on ITER through the U.S. Contributions to ITER MIE project. The ITER MIE TEC funds are budgeted in this subprogram, while the OPC funds are budgeted in the Enabling R&D subprogram.

Supporting Information

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 collaborative 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.

Funding is provided for the continuation of the NCSX MIE project at PPPL. In FY 2008, the project will be in its sixth year and PPPL will continue the fabrication of the major components and assembly of the entire device.

The FY 2008 Request provides for the third year of funding for the U.S. Contributions to ITER MIE project. If there is a reduction in FY 2007 funding, following the reduction in FY 2006, the funding profile will be revised and the TPC will be affected. The FY 2008 TEC funding of $149,500,000 in the Facilities Operations subprogram provides for direct costs for the MIE including U.S. hardware contributions; U.S. personnel assigned to the international ITER Organization; cash for common needs such as infrastructure, hardware assembly, and installation of ITER components; and contingency for the international ITER Organization. The MIE project is being managed by the U.S. ITER Project Office located at ORNL in accordance with DOE Order 413.3A, Program and Project Management for the Acquisition of Capital Assets.

Funding is also included in this subprogram for general plant projects (GPP) and general purpose equipment (GPE) at PPPL. The 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 final year of the five-year effort to support the move of ORNL fusion personnel and facilities to a new location at ORNL.

FY 2006 Facility Operations Accomplishments

In FY 2006, 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:

- A lithium evaporator was installed on NSTX in March 2006 to test the effectiveness of the lithium coating on particle recycling and impurity control. The first experimental test of partially coated plasma facing components using the lithium evaporator was conducted in April – May 2006, and about 1300 mg of lithium have been evaporated to date. Initial experiments with lithium resulted in a large reduction of oxygen impurities in the subsequent plasma discharges.
- PPPL completed winding 4 of the 18 NCSX modular coil winding forms (MCWFs) and fabrication of the 3 vacuum vessel sectors. The MCWFs are steel structures that support the modular coil windings and position them with high accuracy. The vacuum vessel is a highly shaped structure with stringent requirements on vacuum quality and magnetic permeability.
- In FY 2006, Alcator C-Mod's lower hybrid antenna structure was modified, re-installed, and used reliably for the facility's first successful current drive studies. Important diagnostic advances include an imaging hard x-ray camera measuring detailed profiles of the fast electrons driven by the lower hybrid system, multiple spectroscopy views implemented for detailed ion temperature and plasma rotation measurements, and upgrades to the motional stark effect detector system which have greatly improved the signal-to-noise for current profile measurement.
- In FY 2006, DIII-D completed a year-long shutdown period during which an extensive number of facility modifications and enhancements were performed. Collectively called the Long Torus Opening Activities (LTOA), the set of improvements that were successfully completed included:
  - rotation of one of four heating neutral beam lines to inject opposite the other three beam lines (including all the support system modifications);

- installation of a new water cooled lower divertor shelf structure in a collaboration with the Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP);
- initiation of the procurement of three long-pulse microwave sources (gyrotrons) to replace existing short-pulse gyrotrons;
- additions and modifications to the microwave system infrastructure to support the long-pulse tubes and the testing of a new depressed collector gyrotron; and
- approximately 40 diagnostic modifications and improvements (most involving university or laboratory collaborators) that required or made full use of the extended torus opening.

These modifications will greatly enhance the experimental flexibility of DIII-D, maintaining its status as one of the world's leading fusion research facilities.

The table below summarizes the operation of the major fusion facilities.

Weeks of Fusion Facility Operation

	(weeks of operations)		
	FY 2006 Results	FY 2007 Request	FY 2008 Request
DIII-D	12[a]	12	15
Alcator C-Mod	16	15	15
NSTX	12	12	12
Total	40	39	42

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
DIII-D	**30,780**	**32,362**	**34,405**

Support is provided for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. The DIII-D experimental flexibility was greatly increased by the completion of several hardware improvements in FY 2005 and FY 2006. These included acquisition of three long-pulse (10 second) gyrotrons for high power heating and current drive, addition of particle pumping in the lower divertor, rotation of one of the neutral beam lines in order to control plasma rotation, upgrades to one of the fast wave heating systems, and improvements to the cooling tower, power systems, and field coil connections in order for high performance plasmas to be operated for long pulses. In FY 2008, 15 weeks of single shift plasma operation will be conducted, during which time essential scientific research will be performed as described in the science subprogram. Funding will be provided for completion of a facility power infrastructure upgrade to support maximum utilization of the existing auxiliary heating systems, and for modifications to the coil connections to allow long pulse operations.

[a] A refund of prior year tax payments allowed DIII-D to schedule 5 weeks over the total supported by the FY 2006 appropriation.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Alcator C-Mod	**13,032**	**13,941**	**14,322**

Support is provided for operation, maintenance, minor upgrades, and improvement of the Alcator C-Mod facility and its auxiliary systems, including a new 4-strap ion cyclotron radio frequency (ICRF) antenna, a second lower hybrid wave launcher enabling compound spectra to be investigated, a new data acquisition system, and a non-thermal electron cyclotron emission diagnostic. In FY 2008, C-Mod will be operated for 15 weeks, and a few minor facility upgrades will enable additional ITER-relevant experiments in the future.

National Spherical Torus Experiment	**18,681**	**18,422**	**19,972**

Support is provided for operation, maintenance and a few diagnostics upgrades, including the full poloidal charge exchange recombination spectroscopy system, a fast-ion D-alpha camera, divertor diagnostics, and installation of next-step fluctuation diagnostics. Funding of $750,000 for diagnostic upgrades is transferred from research to facility operations in FY 2008. In FY 2008, there is funding for 12 weeks of operation and a few minor facility upgrades that will enable long pulse, high beta experiments in the future.

National Compact Stellarator Experiment	**17,019**	**15,900**	**15,900**

Funding is requested in FY 2008 for the continuation of the NCSX MIE project consistent with the baseline approved in July 2005. This project was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. PPPL will continue the fabrication of the major components and assembly of the entire device. 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.

General Plant Projects/General Purpose Equipment/Other	**3,538**	**3,930**	**2,905**

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 final year of the move of ORNL fusion personnel and facilities to a new location at ORNL.

ITER Preparations	**5,294**	**—**	**—**

Preparations funding for ITER ended in FY 2006 as the U.S. Contributions to ITER MIE project began. Funding was provided to continue the ITER transitional activities such as safety, licensing, project management, preparation of specifications and system integration. U.S. personnel participated in these activities in preparation for U.S. participation in the international ITER project.

U.S. Contributions to ITER	**15,866**	**37,000**	**149,500**

The U.S. Contributions to ITER MIE project provides hardware, personnel, cash for common expenses, and contingency to the international ITER Organization.

ITER has been designed to provide major advances in all of the key areas of magnetically confined plasma science. ITER's size and magnetic field will provide for study of plasma stability and transport in regimes unexplored by any existing fusion research facility worldwide. Owing to the intense plasma

(dollars in thousands)		
FY 2006	FY 2007	FY 2008

heating by fusion products, it will also access previously unexplored regimes of energetic particle physics. Because of the very strong heat and particle fluxes emerging from ITER plasmas, it will extend regimes of plasma-boundary interaction well beyond previous experience. The new regimes of plasma physics that can be explored for long duration, and the interactions among the anticipated phenomena, are characterized together as the new regime of "burning plasma physics."

The ITER design is based on scientific knowledge and extrapolations derived from the operation of the world's tokamaks over the past decades and on the technical know-how flowing from the fusion technology research and development programs around the world. The ITER design has been internationally validated by wide-ranging physics and engineering work, including detailed physics and computational analyses, specific experiments in existing fusion research facilities and dedicated technology developments and tests performed from 1992 to the present.

The ITER device is a long-pulse tokamak with elongated plasma shape and single null poloidal divertor. The nominal inductive operation produces a deuterium-tritium fusion power of 500 MW for a burn duration of 400 to 3000 seconds, with the injection of 50 MW of auxiliary power. This provides a power gain of up to a factor of 10.

Safety and environmental characteristics of ITER reflect a consensus among the parties on safety principles and design criteria for minimizing the consequences of ITER operation on the public, operators, and the environment. This consensus is supported by results of analysis on all postulated events and their consequences.

DOE will comply with all U.S. environmental and safety requirements applicable to the ITER work that will be conducted in the U.S. Compliance with the National Environmental Policy Act for the U.S. effort is consistent with the standard DOE process in support of long-lead procurement for the manufacture of the components.

DOE's commitment to the ITER Organization is a $^{1}/_{11}$th share (about 9.1%) of the international ITER project costs, which is consistent with the other non-host participants. In addition to scientists and engineers assigned to the ITER Organization, the U.S. has provided one senior management staff member to the ITER Organization, specifically Deputy Director General for Tokamak Systems. All U.S. personnel assigned to the project will comply with the environmental and safety requirements of the host country and with the applicable U.S. legal requirements.

As a result of the extensive collaborative efforts during the ITER Engineering Design Activities (EDA) from 1992 to 1998, and its extension from 1999 to 2001, a mature ITER design exists including completed R&D prototypes of critical ITER components.

The MIE funding provides for procurement of hardware, personnel assigned to the project abroad, U.S. share of cash for ITER project common needs (ITER Organization infrastructure, hardware assembly and installation, and testing of U.S. supplied hardware), contingency, and operation of the U.S. ITER Project Office. The Project Office is responsible for management of U.S. Contributions to ITER including management, quality assurance, procurement, and technical oversight of procurements.

DOE requires the U.S. ITER Project Office to assume a broad leadership role in the integration of ITER-related project activities throughout the U.S. Fusion Energy Sciences Program and, as appropriate, internationally. For managing the direct procurements with industry, the Project Office has assembled experts from throughout the fusion program for technical follow-up and execution of the procurements.

The final allocation of equipment to be supplied by the United States, as revised with the inclusion of India, is indicated below.

- Niobium Tin (Nb_3Sn) Superconducting Strand – Niobium, tin and copper filaments formed into long strands. The U.S. will provide 8% of the total needed for the Toroidal Field Magnets.
- Superconducting Cable – multi-stage cable including strand and insulation. The U.S. will provide 8% of the total needed for the Toroidal Field Magnets.
- Central Solenoid – the U.S. has the lead role for this contribution consisting of six modules plus one spare module; and is responsible for module testing oversight and assembly oversight at the ITER site.
- Blanket Modules – a contribution consisting of 36 (of 360) modules around the tokamak vessel (plus 4 spares), 40 cm thick (including plasma facing components and shield).
- Vacuum Pumping Components – a U.S. contribution consisting of components required to create and maintain the vacuum inside the tokamak vessel.
- Tokamak Exhaust Processing System – a U.S. contribution to include recovery of hydrogen isotopes from impurities such as water and methane, delivery of purified, mixed hydrogen isotopes to the Isotope Separation System, and disposal of non-tritium species.
- Heating and Current-Drive Components for Ion Cyclotron Heating frequencies – the U.S. contribution consists of transmission lines.
- Heating and Current-Drive Components for Electron Cyclotron Heating frequencies – the U.S. contribution consists of transmission lines.
- Fueling Injector – provides for an ITER pellet injector.
- Steady-state Electrical Power System – a U.S. contribution consisting of a steady-state electric power network similar in scale and function to an "auxiliary system" of a large power plant.
- Cooling Water System – the ITER tokamak water cooling system is a U.S. contribution including the primary heat transfer system, the chemical and volume control system, and the draining, refilling, and drying system.
- Diagnostics – a U.S. contribution involving 16% of the ITER Diagnostic effort providing six diagnostic systems such as visible and infrared cameras, toroidal interferometer/polarimeter, electron cyclotron emission, divertor interferometer, and residual gas analyzers; five cover plates on the tokamak vessel on which multiple diagnostics from U.S. and other parties are mounted; and integration of diagnostic systems from other ITER parties.

Activities in FY 2008 will include: complete the design for the central solenoid coil fabrication; complete preliminary design and analysis for the central solenoid structure; award procurement of cabling and jacket material for the toroidal field coil conductor; award procurement of strand for the toroidal field coil conductor; issue requests for proposals for first wall and shield module components and award contract to construct first articles; continue the planning, concept development and preliminary design on the port limiter system; start preliminary design of the transmission lines for the ion and electron cyclotron heating systems, and diagnostics; continue conceptual designs for vacuum pumping and fueling systems; award procurements for components of the tokamak cooling water system; monitor design activities with the EU for the steady-state electrical power network; and complete most R&D activities. R&D activities will continue beyond FY 2008 in the areas of the port limiter system, diagnostics, and the tritium plant exhaust processing system.

The schedule and TEC funding profile for the U.S. Contributions to ITER MIE are reflected in the following tables. The MIE project cost estimate for U.S. Contributions to ITER is preliminary until the baseline scope, cost, and schedule for the MIE project is established at CD-2b.

U.S. Contributions to ITER

	Fiscal Quarter				
	Procurements Initiated	Procurements Complete	Personnel Assignments to Foreign Site Start	Personnel Assignments to Foreign Site Complete	Total Estimated Cost ($000)
FY 2006 Budget Request	3Q FY 2006	4Q FY 2012	2Q FY 2006	4Q FY 2013	1,038,000
FY 2007 Budget Request	4Q FY 2006	4Q FY 2012	2Q FY 2006	FY 2014	1,077,051
FY 2008 Budget Request	1Q FY 2008	4Q FY 2014	2Q FY 2006	FY 2014	1,078,230[a]

[a] The funding profile is a preliminary estimate. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The performance baseline, including the funding profile, will be established at CD-2b, planned for late FY 2008. CD-1/2a/3a is planned for late FY 2007–early FY 2008 in order to take advantage of the planned international ITER design review scheduled to begin in early 2007 by the Director General of the ITER Organization. Note that the MIE OPC funding associated with this Total Estimated Cost is budgeted in the Enabling R&D subprogram.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

Financial Schedule
Total Project Costs (TPC)[a]
(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Cost	Total Project Costs
2006	15,866	3,449	19,315
2007	37,000	23,000	60,000
2008	149,500	10,500	160,000
2009	208,500	6,000	214,500
2010	208,500	821	209,321
2011	181,964	—	181,964
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,078,230	43,770	1,122,000

	FY 2006	FY 2007	FY 2008
Total, Facility Operations	**104,210**	**121,555**	**237,004**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
DIII-D	
The increase will support an additional 3 weeks of operation and complete the power systems infrastructure upgrade and modifications to the coil systems needed for long pulse operations. These enhancements will enable maximum utilization of the auxiliary heating systems that were improved in FY 2005 and FY 2006 and extension of advanced operating modes to longer pulse lengths.	+2,043

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The performance baseline, including the funding profile, will be established at CD-2b planned for late FY 2008. Additionally, if there is a reduction in FY 2007 funding, following the reduction in FY 2006, the funding profile will be revised and the TPC will be affected. The Other Project Costs associated with the TEC funding are described in the Enabling R&D subprogram.

	FY 2008 vs. FY 2007 ($000)
Alcator C-Mod	
The increase will allow C-Mod to conduct 15 weeks of operation while performing major upgrades to support ITER-relevant research, including a new 4-strap ICRF antenna, a second lower hybrid wave launcher enabling compound spectra to be investigated, and a non-thermal electron cyclotron emission diagnostic.	+381
National Spherical Torus Experiment	
Nearly one-half of the increase results from transferring $750,000 of equipment funds for diagnostic upgrades from the research budget to the facility operations budget. The remainder ($800,000) provides for expected increases in electricity and cryogens and maintains staff at current levels.	+1,550
GPP/GPE/Other	
The decrease reflects the near completion of the move of fusion personnel and equipment from the Y–12 site to the ORNL site.	-1,025
U.S. Contributions to ITER (MIE Total Estimated Cost)	
This increase provides for the third year of funding for the Major Item of Equipment project and is consistent with the stated project cost and schedule profile. Activities in FY 2008 will include advancement and/or completion of various design and analysis activities and initiation of procurements for major U.S. components.	+112,500
Total Funding Change, Facility Operations	**+115,449**

Enabling R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Enabling R&D			
Engineering Research	17,316	15,495	16,002
Enabling R&D for ITER (Other Project Costs)	3,449	23,000	10,500
Materials Research	7,066	4,687	4,815
Total, Enabling R&D	27,831	43,182	31,317

Description

The mission of the Enabling R&D subprogram is to develop the cutting edge technologies that enable both U.S. and international fusion research facilities to achieve their goals.

Benefits

The foremost benefit of this subprogram is that it enables the scientific advances in plasma physics accomplished within the Science subprogram. That is, the Enabling R&D subprogram develops, and continually improves, the hardware and systems that are incorporated into existing fusion research facilities, thereby enabling these facilities to achieve higher and higher levels of performance within their inherent capability. In addition, the Enabling R&D subprogram supports the development of new hardware that is incorporated into the design of next generation facilities, thereby increasing confidence that the predicted performance of these new facilities will be achieved. Finally, there is a broader benefit beyond the fusion program in that a number of the technological advances lead directly to “spin offs” in other fields, such as superconductivity, plasma processing and materials enhancements.

Supporting Information

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 and increasing amount of the research is oriented toward the technology needs of future experiments, such as ITER. Enabling R&D efforts provide both evolutionary development advances in present day capabilities that will make it possible to enter new plasma experimental regimes, such as burning plasmas, and nearer-term technology advancements enabling international technology collaborations that allow the U.S. to access plasma experimental conditions not available domestically. A part of this element is oriented toward investigation of scientific issues for innovative technology concepts that could make revolutionary changes in the way that plasma experiments are conducted, such as microwave generators with tunable frequencies and steerable launchers for fine control over plasma heating and current drive. This element includes research on blanket technologies that will be needed to produce and process tritium for self-sufficiency in fuel supply. This element also supports research on safety-related issues that enables both current and future experiments to be conducted in an environmentally sound and safe manner. Another activity is conceptual design of the most scientifically challenging systems for fusion research facilities that may be needed in the 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 of fusion.

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 uses both experimental and modeling activities, which makes it more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded by the Basic Energy Sciences program and other government-sponsored programs, as well as making it 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 nearer-term fusion devices, such as burning plasma experiments, 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 nanoscale design of advanced fusion materials with superior performance and lifetime.

Management of the diverse and distributed collection of technology R&D activities continues to be accomplished through a Virtual Laboratory for Technology (VLT), with community-based coordination and communication of plans, progress, and results.

In FY 2008, research efforts will continue supporting the development of enabling technologies that enhance plasma performance on both our current and planned domestic machines as well as for our international collaborations with existing facilities such as JET and possibly with new facilities such as Korea's KSTAR and China's EAST. In addition, resources will be used to continue to develop a data base for materials that can be used in future facilities, to address potential issues that may occur during ITER operation, and to develop the next generation of technology that could be tested in current facilities or in ITER. The Enabling R&D for ITER (Other Project Costs) element will continue to fund R&D in a number of areas, including magnets, first wall/shield modules, tritium processing, fueling and pumping, heating systems, and diagnostics, which directly support the U.S. ITER hardware contributions.

FY 2006 Enabling R&D Accomplishments

A number of technological advances were made in FY 2006. Examples include:

- Use of ITER as a testing environment for integrated first wall and tritium breeding blanket science and technology research has been a principal objective of ITER since its inception and has drawn considerable interest from all ITER parties. The U.S. fusion technology community, in a collaborative effort among researchers, have completed a draft technical plan and cost estimate for a U.S. ITER Test Blanket Module (TBM) program based on two TBM concepts (a dual-coolant liquid breeder concept and a helium-cooled ceramic breeder concept). While the TBM program is not part of the ITER MIE scope and it falls outside of the ITER TPC, the completion of this draft report is an important step toward preparing for possible U.S. participation in the ITER first wall/blanket testing program.
- First experiments studying the effects of strong magnetic fields on turbulent flow and heat transfer in pipes were performed this year at the University of California at Los Angeles (UCLA) as part of the

on-going JUPITER-II collaboration between the U.S. and Japan (DOE-MEXT). These novel experiments used a transparent electrolyte as a working liquid so that laser based velocity diagnostics could be used to map out details of the flow field for comparison to sophisticated Direct Numerical Simulation models of MHD turbulence. In addition, heat transfer experiments were also performed to directly correlate how modifications in ordinary turbulence by MHD effects reduce the heat transfer capability of the liquid. It was found that the heat transfer capability had been reduced by 32% at even very modest magnetic interaction.

- As part of the U.S.-Japan (DOE-JAEA) fusion materials collaboration, the first set of experiments exploring the transport and fate of helium in reduced activation ferritic-martensitic steels and nanostructured ferritic alloys was completed. Fusion relevant helium levels were investigated by applying thin nickel alumina coatings on transmission electron microscopy discs. Under irradiation, these coatings produced alpha particles that are deposited in the adjacent material. The effects of microstructural features on helium bubble density and size can be studied in great detail. This work has shown that nanostructured ferritic alloys more efficiently trap helium than conventional reduced activation ferritic-martensitic steels. Design of helium-tolerant microstructures will be possible as the result of this research.
- Massachusetts Institute of Technology (MIT), in collaboration with the Universities of Maryland and Wisconsin, Communications and Power Industries of Palo Alto, CA, Calabasas Creek Inc., and General Atomics, report operation of a 110 GHz, depressed collector gyrotron at a power level of 1.5 MW with an efficiency exceeding 50%. High power gyrotrons operating at greater than 50% efficiency are needed for heating large-scale plasmas, including the DIII-D tokamak and ITER. The improved efficiency was obtained with a new gyrotron resonator design that also yields reduced ohmic losses. The gyrotron, which has an internal mode converter, operated at MIT in three microsecond pulses of 96 kV and 40 A. Up to 25 kV of voltage depression was used to improve the efficiency. In the next step, these improved results should be tested in an industrial, long pulse version of the gyrotron.
- The pellet fueling scenario for ITER has been modeled using codes validated with DIII-D and other experimental results. The model shows that fuel from high field side launched pellets should be able to penetrate beyond the expected H-mode pedestal region into the core plasma and provide sufficient fueling to maintain ITER at high plasma density.
- The Divertor Materials Exposure Sample (DiMES) on DIII-D was used to measure carbon deposition in a gap between tiles (similar to that on ITER). The measured deposition profile was used to estimate tritium trapping on ITER and was found to be consistent with previous trapping estimates. The DiMES was also used to expose samples of diagnostic mirrors for ITER which produced an important new result which is that elevated temperatures greatly reduce the deposition of carbon on the mirror surface. This is good news for ITER diagnostics.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Engineering Research	**17,316**	**15,495**	**16,002**
▪ **Plasma Technology**	**14,787**	**12,945**	**13,452**

Plasma Technology efforts will focus resources on developing enabling technologies for current and future machines, both domestically and internationally, and on addressing potential ITER operational issues in the area of safety and plasma materials interactions. In addition, a new U.S.-Japan Collaborative Program (Jupiter III) will be initiated on plasma facing and blanket materials for use in future experiments and in testing high efficiency gyrotrons. During FY 2008, the following specific elements will be supported:

- Continue testing of a highly efficient 110 gigahertz, 1–1.5 megawatt industrial prototype gyrotron microwave generator, the most powerful and efficient of its kind for electron cyclotron heating of plasmas.
- Studies will continue in the Plasma Interaction with Surface and Components Experimental Simulator (PISCES) facility at the University of California at San Diego (UCSD), and the Tritium Plasma Experiment at the Idaho National Laboratory (INL), of tungsten-carbon-beryllium mixed materials layer formation and redeposition with attached hydrogen isotopes. Results will be applied to evaluate tritium accumulation in plasma facing components that will occur during ITER operation.
- In the Safety and Tritium Applied Research Facility (STAR) at INL, a new series of material science experiments will be initiated under the current cost-sharing collaboration with Japan (Jupiter III) to resolve key issues of tritium behavior in materials proposed for use in fusion systems.

Additional funds will be provided for research on plasma facing components, heating technologies, and blanket concepts that could be tested in ITER. Funds will also be provided for research in safety and plasma-surface interaction and modeling that will support potential issues that will be encountered during ITER operation.

▪ **Advanced Design**	**2,529**	**2,550**	**2,550**

Funding for this effort will continue to focus on studies of fusion concepts for the future. Systems studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics of such advanced magnetic confinement concepts will be conducted in an iterative fashion with the experimental community.

Enabling R&D for ITER (Other Project Costs)	**3,449**	**23,000**	**10,500**

Enabling R&D funds for ITER activities are identified in FY 2008 for R&D in support of equipment in a number of areas including magnets, first wall/shield modules, tritium processing, fueling and pumping, heating systems, and diagnostics, which would be provided by the U.S. to ITER. This R&D continues to be applicable to future burning plasma experiments.

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

The MIE project cost estimates for U.S. Contributions to ITER, including the Other Project Costs activities provided in the table below, are preliminary until the baseline scope, cost and schedule for the MIE project are established.

Financial Schedule

Total Project Costs (TPC)[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Cost	Total Project Costs
2006	15,866	3,449	19,315
2007	37,000	23,000	60,000
2008	149,500	10,500	160,000
2009	208,500	6,000	214,500
2010	208,500	821	209,321
2011	181,964	—	181,964
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,078,230	43,770	1,122,000

	FY 2006	FY 2007	FY 2008
Materials Research	**7,066**	**4,687**	**4,815**

Materials Research remains the key element in establishing the scientific foundations for safe and environmentally attractive uses of fusion as well as providing solutions for materials issues faced by other parts of the FES research program. The FY 2008 request will maintain a small, but highly beneficial Materials Research program that addresses material needs for nearer and longer term fusion devices. The funding will be used for both modeling and experimental activities aimed at the science of materials behavior in fusion environments, including research on candidate materials for the structural elements of fusion chambers. Two cost-shared international collaborations (DOE/JAEA and Jupiter III) focusing on irradiation testing of candidate fusion materials in U.S. facilities will continue.

	FY 2006	FY 2007	FY 2008
Total, Enabling R&D	**27,831**	**43,182**	**31,317**

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. During FY 2007 and early FY 2008, U.S. reviews are scheduled to validate the cost and schedule estimates for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2007 and FY 2008 will also validate the international cost and schedule which can have an affect on the U.S. Contributions to ITER project. The performance baseline, including the funding profile, will be established at CD-2b planned for late FY 2008. The Total Estimated Cost associated with the OPC funding is budgeted in the Facilities Operations subprogram.

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Engineering Research	
▪ **Plasma Technology**	
The increase will support both heating and magnet programs.	+507
Enabling R&D for ITER (Other Project Costs)	
The decrease is consistent with the revised stated cost and schedule estimate for the ITER MIE project. The FY 2008 OPC funding level is decreased as is customary in an MIE project when the design and R&D needs are resolved or completed and the project is moving into procurement and fabrication.	-12,500
Materials Research	
The increase is due to additional costs for international collaborations with Japan.	+128
Total Funding Change, Enabling R&D	**-11,865**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	1,791	1,810	1,900
Capital Equipment	39,603	57,765	169,050
Total, Capital Operating Expenses	41,394	59,575	170,950

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Completion Date
NCSX (31MB), PPPL	101,971	92,401	41,318	17,019	15,900	15,900	FY 2009
U.S. Contributions to ITER (61PA), Cadarache, France	1,122,000[a]	1,078,230[a]	—	15,866	37,000	149,500	FY 2014
Total, Major Items of Equipment				32,885	52,900	165,400	

[a] Funding is for the third year of the Major Item of Equipment project, U.S. Contributions to ITER and is considered preliminary until the performance baseline is established at CD-2b, planned for late FY 2008. The funding cap of $1,122,000,000 TPC is maintained. The TPC funding cap could change if changes in escalation and/or fluctuations in the current exchange rates occur prior to CD-2b. The estimates incorporate the key results of the December 2005 negotiations and have been prepared based upon (1) U.S. industrial estimates for the hardware items the United States will contribute, (2) estimates for personnel to be assigned abroad consistent with previous experience during the ITER Engineering Design Activities, (3) U.S. cash contributions for a non-host participant in the ITER project, and (4) estimates for operation of the U.S. ITER Project Office including technical oversight of procurement.

Science Laboratories Infrastructure

Funding Profile by Subprogram

(dollars in thousands)

	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Science Laboratories Infrastructure			
Laboratories Facilities Support	22,165	29,461	65,049
Excess Facilities Disposition	14,491	16,348	8,828
Oak Ridge Landlord	5,028	5,079	5,079
Total, Science Laboratories Infrastructure	41,684[a]	50,888	78,956

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the Science Laboratories Infrastructure (SLI) program is to support 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, general plant projects, and cleanup and removal of excess facilities to maintain the general purpose infrastructure. The program also supports SC stewardship responsibilities for over 24,000 acres of the Oak Ridge Reservation (ORR) and the Federal facilities in the town of Oak Ridge, and provides Payment in Lieu of Taxes (PILT) to local communities around Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), and Oak Ridge National Laboratory (ORNL).

Benefits

This program supports SC's research missions at SC laboratories, primarily by addressing general purpose facilities and infrastructure needs.

Significant Program Shifts

In FY 2006, the Continuous Electron Beam Accelerator Facility (CEBAF) Center Addition, Phase I, at the Thomas Jefferson National Accelerator Facility (TJNAF), was completed on schedule, and within budget and scope.

FY 2008 funding of $35,000,000 is held in reserve pending resolution of issues related to capability replacement and renovation of facilities at Pacific Northwest National Laboratory (PNNL).

External Independent Reviews

The costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $100,000,000 within SC are funded by SC. Examples of EIRs include conducting Performance Baseline EIRs prior to Critical Decision-2 (CD-2) to verify the accuracy of cost and schedule baseline estimates and conducting Construction/Execution Readiness EIRs, which are done for all Major System projects

[a] Total is reduced by $421,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

prior to CD-3. These funds, which are managed by the Office of Engineering and Construction Management, are exclusively used for EIRs directly related to the projects funded by SC.

Laboratories Facilities Support

Funding Schedule by Activity

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Laboratory Facilities Support			
General Purpose Facilities	12,376	14,671	56,529
Environment, Safety and Health (ES&H)	5,314	13,270	7,000
Payment in Lieu of Taxes (PILT)	1,505	1,520	1,520
General Plant Projects (GPP)	2,970	—	—
Total, Laboratories Facilities Support	22,165	29,461	65,049

Description

The Laboratories Facilities Support (LFS) subprogram supports the mission of the Office of Science (SC) by providing funding for line item construction to maintain the general purpose infrastructure, and for Payment in Lieu of Taxes (PILT) to local communities around Argonne and Brookhaven National Laboratories.

Benefits

This subprogram improves the mission readiness of SC laboratories by refurbishing and replacing general purpose facilities and site-wide infrastructure, and by providing financial assistance to communities around Brookhaven National Laboratory and Argonne National Laboratory.

Supporting Information

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 ten SC research laboratories, and the Oak Ridge Institute for Science and Education (ORISE), together have 1,519 buildings and real property trailers, with 21.5 million gross square feet of space that are aging. Over 6,000 employees and users of SC research facilities are housed in wooden buildings, trailers and buildings more than 50 years old. The average age of active SC buildings is 34 years. In terms of square footage, 55% (11.6 million square feet) is 40 years old or older, including 30% (6.4 million square feet) that is over 50 years old.

As required by DOE Order 430.1B, Real Property Asset Management, SC laboratories have prepared Ten Year Site Plans (TYSPs). These plans identify facility and infrastructure investments needed for real property assets to support mission requirements.

These TYSPs have identified a number of infrastructure needs that are primarily attributable to:

- the age of the facilities;
- the use of wood and other non-permanent building materials in the original construction of the laboratories in the 1940’s and 1950’s;

- changing research needs that require:
  - different kinds of facilities (e.g., nuclear facilities, such as hot cells, are in lower demand, while facilities that foster interaction and team-based research are in higher demand) and
  - higher quality facilities (e.g., reduced vibration and temperature variability, better air quality and increased power capability for computers and other electronic equipment);
- obsolescence of existing building systems and components, and changing technology (e.g., digital controls for heating and ventilation systems, fire alarms and security);
- need for improved reliability of utility operations to support the large number of researchers at SC user facilities; and
- changing environmental, safety and health regulations, and security needs.

All candidate construction projects are scored by the respective sites using the DOE Capital Asset Management Process (CAMP), which takes into account risk, impacts, and mission need. Those projects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the former DOE ES&H and Infrastructure Management Plan process. The projects are then evaluated by the LFS subprogram to establish a cross SC ranking. This is done by normalizing the site scoring and ensuring that available funds are distributed across the laboratories in accordance with SC program priorities. Selection of projects for funding is coordinated with SC program offices to confirm prioritization.

The LFS subprogram ensures that the funded subprojects are managed effectively and completed within the established cost, scope, and schedule baselines. Performance is measured by the number of all SLI subprojects completed within the approved baseline for cost, scope (within 10%), and schedule (within six months). For example, in FY 2006, the CEBAF Center Addition subproject was completed within its cost, scope, and schedule baseline.

SLI construction subprojects typically involve conventional construction and, as such, can usually be engineered, designed, and ready for construction contract award within one fiscal year. Accordingly, SLI construction subprojects are submitted with both Project Engineering and Design (PED) and construction funding identified. In most cases, these subprojects proceed (after normal reviews and approvals) directly from design into construction without delay. The Department's December 2000 report to Congress, "The U.S. DOE Implementation Procedures for the Use of External Independent Reviews and Project Engineering and Design Funds," allows this approach under the Section "Simplified Process for a Design-Procure-Build or Design-Build Project," pages 15 to 18. The full report can be found at the following web site: http://www.sc.doe.gov/sc-80/sc-82/documents/EIR-PED.pdf.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
General Purpose Facilities	**12,376**	**14,671**	**56,529**

Provides funding for three subprojects identified below. More detail is provided in construction project data sheet MEL-001. FY 2008 funding includes $35,000,000 held in reserve pending resolution of issues related to capability replacement and renovation at PNNL. If the issues are resolved, DOE will

	FY 2006	FY 2007	FY 2008
(dollars in thousands)			

initiate a reprogramming request to use these funds for replacing and/or upgrading mission-critical facilities currently located in the Hanford Site 300 Area.

Ongoing:

- Modernization of Laboratory, Building 4500N, Wing 4, Phase I, at Oak Ridge National Laboratory (ORNL), which will rehabilitate a facility housing many of the laboratory's chemical laboratory facilities, as well as administrative offices and the medical clinic ($7,329,000);
- Building Electrical Services Upgrade, Phase II, at ANL, which will upgrade critical portions of the electrical power distribution system in 12 research buildings and support facilities, including the Canal Water Plant supplying cooling water for site experiments ($6,000,000); and
- Renovate Science Laboratory, Phase I, at BNL, which will upgrade and rehabilitate existing obsolete and unsuitable laboratory facilities into modern, efficient facilities compatible with world-class scientific research ($8,200,000).

Environment, Safety and Health	**5,314**	**13,270**	**7,000**

Provides funding for one subproject identified below. More detail is provided in construction project data sheet MEL-001.

Ongoing:

- Seismic Safety Upgrade of Buildings, Phase I, at Lawrence Berkley National Laboratory (LBNL), which will address the seismic vulnerability of laboratory buildings where high life-safety risks have been identified ($7,000,000).

Payment in Lieu of Taxes (PILT)	**1,505**	**1,520**	**1,520**

Provides PILT to support assistance requirements for communities around Brookhaven National Laboratory and Argonne National Laboratory. PILT payments are negotiated between the Department and local governments based on land values and tax rates.

General Plant Projects (GPP)	**2,970**	**—**	**—**

Provides funding for GPP projects (Total Estimated Cost less than $5,000,000) to refurbish and rehabilitate general purpose infrastructure necessary to perform research throughout the SC Laboratory complex. Funding for GPP in FY 2007 and FY 2008 is contained in other SC program budgets.

Total, Laboratories Facilities Support	**22,165**	**29,461**	**65,049**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
General Purpose Facilities (GPF)	
▪ The increase is due to the inclusion of funding (+$35,000,000) held in reserve pending resolution of issues related to the capability replacement and renovation effort for facilities located in the Hanford Site 300 Area; and, for increased funding, per schedule, of the four subprojects requested in FY 2007.	+41,858
Environmental Safety & Health (ES&H)	
▪ The decrease is due primarily to completion of funding for the Stanford Linear Accelerator Center (SLAC) Safety and Operational Reliability Improvements subproject in FY 2007.	-6,270
Total Funding Change, Laboratories Facilities Support	**+35,588**

Excess Facilities Disposition

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Excess Facilities Disposition	14,491	16,348	8,828

Description

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 also supports cleanup of facilities for reuse when such reuse is economical and provides needed functionality.

Benefits

This subprogram reduces the long-term costs, risks, and liabilities at the SC laboratories associated with excess facilities by removing them or cleaning them up for reuse or transfer. It also supports programmatic initiatives by making land available for new programs, by reducing expenditures on surveillance and maintenance of excess facilities and by providing space to offset new construction, in accordance with the Congressional requirement to offset new building space with the removal of existing building space.

Supporting Information

SC has a current backlog of facilities whose cost of disposal (i.e., demolition or cleanup for reuse) is estimated to be $325,000,000. The EFD subprogram evaluates and prioritizes this 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 representing the EFD subprogram and SC research program offices.

In FY 2008, the EFD subprogram will continue funding for decontamination and demolition (D&D) of Building 51 and the Bevatron at LBNL. This effort, whose total project cost is estimated to range from $65,000,000 to $75,300,000, will, by FY 2011, eliminate a legacy facility which ceased operation in 1993, and free up 125,040 square feet—approximately 7.5% of the total usable land at the LBNL site—for programmatic use. Both laboratory and office space are in critically short supply at LBNL. The shortage of onsite space has necessitated leasing of approximately 95,000 square feet in offsite buildings. Continued reliance on an aged and decaying physical plant impedes research, reduces productivity, and makes recruitment and retention of top-quality scientists and engineers much more difficult. Removal of Building 51 and the Bevatron will free up land for re-development to support on-going and new mission activities.

The original D&D approach for Building 51 and the Bevatron was to use the existing 50 year old crane in Building 51, which covers the Bevatron, to remove the shielding blocks and beam line. The speed of the crane meant the project would take four to five years. A review team proposed an alternative approach of first removing Building 51 entirely and then employing two or more modern cranes to remove the shielding blocks and beam line quickly and efficiently. This new approach which was selected at Critical Decision 1—Approve Alternative Selection and Cost Range—allows the removal portion of the project to be completed over a two year period, reducing project costs 10 to 20% and increasing safety. Funding provided in FY 2008 and remaining funding from prior years will be consolidated and used to support removal work over two adjacent fiscal years in the near future.

The EFD subprogram will also fund demolition of legacy facilities at ANL, BNL, and ORNL, whose continued deterioration presents an increasing risk to the workers and the environment, and for which SC can "bank" space to meet the requirement for offsetting new construction with elimination of excess space.

The EFD subprogram does not fund projects that replace currently active and occupied 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 projects.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Excess Facilities Disposition	**14,491**	**16,348**	**8,828**

In FY 2006, funding supported the projects listed below and allowed for the cleanup/removal of an estimated 107,000 square feet of space:

- Ames ($45,000) – Completion of the Closeout and Demolition of the Waste Handling Facility and the Hydrogen Test Cell Facility (9,900 square feet)
- ANL ($770,000) – Demolition of Buildings 374A, and 40, Phase II, and Site Beryllium Remediation, Phase I, (approximately 11,000 square feet)
- BNL ($600,000) – Completion of demolition of Buildings 197, 527, 933B and 934, and demolition of Buildings 86, 422A (partial), 482, 628, 649 and 650, Phase I (approximately 19,000 square feet)
- Fermi National Accelerator Laboratory (FNAL) ($125,000) – Demolition of Trailers T-017, T-024, T-025 and T-069 (approximately 1,440 square feet)
- LBNL ($10,900,000) – This funding supported surveys and planning activities required to execute the total removal of the Building 51 and the Bevatron complex, including: preparation of project documentation, engineering plans and specifications, waste management plan, characterization plan, health & safety plan, and community relations plan
- Lawrence Livermore National Laboratory (LLNL) ($150,000) – Demolition of SC Trailer 4325 and Building 363 (approximately 3,700 square feet)
- ORISE ($768,000) – Demolition of Buildings SC-2, Isotope Laboratory, and SC-5, Large Animal Containment Facility (approximately 6,600 square feet)
- ORNL ($858,000) – Demolition of Solway and Freels Bend Excess Facilities (approximately 50,000 square feet)

FY 2006 funding also included $275,000 to conduct External Independent Reviews (EIRs) of SLI projects.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

In FY 2007, funding will support the projects listed below, allowing the cleanup/removal of an estimated 22,000 square feet of space:

- ANL ($500,000) – Building 205 F-111 Vault Cleanup & Hood Demolition (Phase 3 Vault/Corridor Cleanup)
- BNL ($697,000) – Continued demolition of Building 650 Hot Laundry Facility
- LBNL ($14,000,000) – Continued demolition of the Bevatron
- ORNL ($976,000) – Cleanout and deactivation of Building 3503, and demolition of Buildings 3008, 3111, and 2018 (approximately 22,000 square feet)

FY 2007 funding also includes $175,000 to conduct External Independent Reviews (EIRs) of SLI construction projects.

In FY 2008, funding will support the projects listed below, allowing the cleanup/removal of an estimated 41,000 square feet of space:

- ANL ($469,000) – Demolition of Building 40 Calibration Lab (approximately 4,900 square feet)
- BNL ($650,000) – Demolition of Building 130 Office Facility (approximately 20,000 square feet)
- LBNL ($6,145,000) – Continued demolition of the Bevatron
- ORNL ($1,289,000) – Demolition of multiple small buildings and trailers, e.g., Museum Office Trailer-XC1405, ESD/NOAA USAF Instrument Trailer-822, Temporary Waste Storage Facility-7020B and Temporary Waste Storage Facility-7020C (approximately 23,000 square feet)

FY 2008 funding also includes $275,000 to conduct External Independent Reviews (EIRs) of SLI construction projects.

Note: Individual EFD 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	**14,491**	**16,348**	**8,828**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Excess Facilities Disposition	
▪ The decrease is due to reduction in funding for demolition of the Bevatron at LBNL.	-7,520

Oak Ridge Landlord

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Oak Ridge Landlord	5,028	5,079	5,079

Description

The Oak Ridge Landlord subprogram supports activities to maintain continuity of operations at the Oak Ridge Reservation (ORR) and the Oak Ridge Service Center (OR).

Benefits

This subprogram maintains continuity of operations at ORR and OR by minimizing interruptions due to infrastructure and/or other systems failures. The subprogram also provides Payment in Lieu of Taxes (PILT) assistance to communities around Oak Ridge.

Supporting Information

The 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, and DOE facilities in the town of Oak Ridge. The supported activities include maintenance of roads, grounds and other infrastructure, support and improvement of environment, safety and health (ES&H) posture, payment of PILT to Oak Ridge communities, and other needs related to landlord responsibilities. These activities maintain continuity of operations at the ORR and OR, and minimize interruptions due to infrastructure and/or other systems failures.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Roads, Grounds and Other Infrastructure and ES&H Support and Improvements	**1,981**	**2,051**	**2,300**
General Purpose Equipment (GPE)	**219**	**—**	**—**
General Plant Projects (GPP)	**—**	**200**	**100**
Major road repair.			
Payment in Lieu of Taxes (PILT)	**2,550**	**2,550**	**2,550**
PILT to the City of Oak Ridge, and Anderson and Roane Counties.			
Reservation Technical Support	**278**	**278**	**129**
Includes meteorological monitoring system, public warning siren system, ORR command media, records management, mapping, and real estate activities.			
Total, Oak Ridge Landlord	**5,028**	**5,079**	**5,079**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
General Plant Projects	2,970	200	100
General Purpose Equipment	219	—	—
Total, Capital Operating Expenses	3,189	200	100

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2006	FY 2007	FY 2008	Unapprop. Balance
07-SC-04, Project Engineering Design, Various Locations	8,908	—	—	8,908	—	—
04-SC-01, Physical Sciences Facility (PNNL), Project Engineering Design	27,486[a]	5,946	2,970	—	—	—
MEL-001, Science Laboratories Infrastructure Project	N/A	N/A	14,720	19,033	63,529[b]	N/A
Total, Construction			17,690	27,941	63,529	

[a] Includes $8,916,000 of PED funded in SC; $16,570,000 of PED funded in NNSA; and $2,000,000 of PED funded in DHS.
[b] FY 2008 funding includes $35,000,000 held in reserve pending resolution of issues related to capability replacement and renovation at PNNL. If the issues are resolved, DOE will initiate a reprogramming request to use these funds for replacing and/or upgrading mission-critical facilities currently located in the Hanford Site 300 Area.

Science Program Direction

Funding Profile by Subprogram

(dollars in thousands/whole FTEs)

	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Science Program Direction			
Program Direction	68,155	75,045	80,741
Field Operations	90,963	95,832	104,193
Total, Science Program Direction	159,118[a]	170,877	184,934
Staffing			
Program Direction (FTEs)	313	366	386
Field Operations (FTEs)	636	648	672
Total, FTEs	949	1,014	1,058

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of Science Program Direction (SCPD) is to provide a Federal workforce, skilled and highly motivated, to manage and support basic energy-related and science-related research disciplines, diversely supported through research programs, projects, and facilities under the Office of Science's (SC's) leadership.

SCPD consists of two subprograms: Program Direction and Field Operations. The Program Direction subprogram is the single funding source for the Federal staff in SC Headquarters (HQ) responsible for SC policy and direction, as well as program development and management of the broad spectrum of SC scientific disciplines. This subprogram includes planning and analysis activities, providing the capabilities needed to evaluate and communicate the scientific excellence, relevance, and performance of SC basic research programs. Additionally, Program Direction includes funding for the Office of Scientific and Technical Information (OSTI), which collects, preserves, and disseminates Research and Development (R&D) information of the Department of Energy (DOE) for use by DOE, the scientific community, academia, U.S. industry, and the public to expand the knowledge base of science and technology. The Field Operations subprogram is the centralized funding source for the Federal workforce within the Field complex responsible for program implementation (Site Offices located at SC laboratories) and for providing best-in-class business, administrative, and specialized technical support across the entire SC enterprise and to other DOE programs through the Integrated Support Center (ISC), operated in partnership by the Chicago (CH) and Oak Ridge (OR) offices.

[a] Total is reduced by $1,607,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

Significant Program Shifts

- The FY 2008 SCPD budget request of $184,934,000 is 4.2% of the total SC FY 2008 budget request of $4,397,876,000 and supports a total of 1,058 full-time equivalents (FTEs), an increase of 44 FTEs over the FY 2007 Budget. The 44 FTE increase is detailed below.
  - 29 new FTEs will allow the hiring of Program Managers and support staff in SC HQ Program Offices to fully and competently manage and support a significantly increased SC research investment that is a major component of the President's American Competitiveness Initiative. In addition, this increase will address specific staffing concerns identified by current Committee of Visitor (COV) reports.
  - 4 new FTEs will enhance support for SC activities; 2 support staff for the National Synchrotron Light Source (NSLS)-II Federal Project Office at the Brookhaven Site Office; and 2 support staff for the ITER Federal Project Office at the OR Office.
  - 35 transferred FTEs reflect staffing for the New Brunswick Laboratory (NBL), which is administered by the Chicago Office and located on the campus of the Argonne National Laboratory. These FTEs were previously supported by the former Office of Security and Safety Performance Assurance (SP).
  - 24 FTEs are reduced across the SC complex consistent with the OneSC FTE outyear approach initiated in FY 2006. The reduction will be accomplished through attrition and workforce management incentives.
- The FY 2008 SCPD budget request is an increase of $14,057,000 over FY 2007. Of this increase, $5,681,000 will directly support salaries, benefits, travel, training, and associated support expenses related to 33 additional program and project managers and associated support staff at HQ and the Field (see previous bullet). Beginning in FY 2008, $6,644,000 is included for NBL previously funded by the former SP. The remaining portion of the increase, $1,732,000, encompasses escalation for payroll, including a 2.2% pay raise in January 2008, an increased cap for Senior Executive Service (SES) basic pay, and other pay related costs such as the government's contributions for employee health insurance and retirement. Also included are increases for non-pay activities such as fixed operating expenses (rent, utilities, and communications contracts), supplies, equipment, and other services. Non-FTE support activities included within the SCPD request include e-Government (e-Gov) initiative fees, OMB Circular A-123 requirements, Standard Accounting and Reporting System (STARS) operation and maintenance assessments, and the OR Financial Service Center Payment Processing Most Efficient Organization (MEO), which provides payment services for the entire nation-wide DOE complex.
- A Human Capital Advisory Group has been established within SC to champion human capital initiatives designed to ultimately align the future SC workforce to deliver on its mission needs. SC is working to attract and retain a capable and proficient workforce to ensure existing continuity and the future of its basic research programs. This is a challenge faced by many agencies, and is particularly acute for SC given the high degree of specialized knowledge and technical qualifications required of its workforce. Getting the right people with the right skills and knowledge in the right jobs is the goal of SC's human capital management efforts. Within SC, procedures and processes are being developed that will provide a consistent approach to workforce planning across the SC enterprise. These procedures and processes will: 1) facilitate understanding of the SC skills mix; 2) identify positions for succession planning; 3) develop a pipeline for critical occupations at all levels of the organization using innovative and strategically deployed recruitment, retention, and developmental

tools; 4) reinforce a results-oriented performance culture, placing significant emphasis on and linking of performance, pay and expectations; and 5) use customer service standards and Office of Personnel Management (OPM) hiring timelines as measures to continually improve recruitment timelines.

- The Department completed an A-76 competitive sourcing study of its information technology (IT) services functions in July 2005. The IT services will be performed by federal employees under the provisions of the MEO in one of the first public/private partnerships between federal and contractor workforce. IT infrastructure services will be consolidated across the Department, as well as support for other IT life-cycle services including cyber security. The FY 2008 request for SCPD reflects a transfer of $966,000 to the Departmental Administration account. These funds represent the SC MEO FTE contribution.

Program Direction

Funding Profile by Category

	(dollars in thousands/whole FTEs)		
	FY 2006	FY 2007	FY 2008
Headquarters			
Salaries and Benefits	46,494	50,942	57,931
Travel	1,911	2,814	2,500
Support Services	10,567	11,141	10,262
Other Related Expenses	9,183	10,148	10,048
Total, Headquarters	68,155	75,045	80,741
Full Time Equivalents	313	366	386

Mission

The Program Direction subprogram funds all of the SC Federal staff in HQ responsible for SC-wide issues and operational policy, scientific program development, and management functions supporting the broad spectrum of scientific disciplines and program offices. These Program Offices include Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, Nuclear Physics, and Workforce Development for Teachers and Scientists. Additionally, this subprogram supports management of workforce program direction and infrastructure through policy, technical, and administrative support staff responsible for: budget and planning; general administration; IT; infrastructure management; construction management; safeguards and security (S&S); and environment, safety and health (ES&H) within the framework set by the Department.

Funding for OSTI is also provided within this subprogram activity. OSTI is responsible for the development and operation of DOE's leading e-Government systems such as the Information Bridge, Energy Citations Database, and the E-Print Network. OSTI also developed and hosts the interagency e-Government system Science.gov, which simultaneously searches across 50 million pages in 30 federal databases involving 12 different federal agencies. Although the majority of DOE's R&D output is open to the scientific community, a sizable share is classified or sensitive. Here, OSTI's responsibilities are to ensure protection and limited, appropriate access in order to promote national security.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Salaries and Benefits	**46,494**	**50,942**	**57,931**

The FY 2008 request supports 386 FTEs at HQ and addresses staffing concerns identified by recent COV reports. This is an increase of 20 FTEs over FY 2007 and comprises two parts. First, an increase of 29 additional FTEs, including Program Managers and support staff, is for the SC HQ Program Offices. The 29 additional Program Managers and support staff are required to ensure sound scientific program development and competent management and support of the SC research investment. Second, an

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

offsetting reduction, accomplished by means of attrition and other workforce incentives, of 9 FTEs across the HQ programs, is consistent with the OneSC FTE outyear approach initiated in FY 2006.

The FY 2008 salary and benefit request assumes a 2.2% pay raise in January 2008; increased cap for SES basic pay; and other pay-related costs such as the government's contributions for employee health insurance and retirement. In addition, innovative and strategically deployed recruitment, relocation, and retention bonuses will be employed corporately to attract and retain technically skilled and highly qualified employees.

Travel	**1,911**	**2,814**	**2,500**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations; and enables HQ staff to effectively manage a broad spectrum of scientific disciplines at geographically dispersed locations and attend numerous site, project, and program reviews; operational policy reviews and meetings; and training for skill maintenance and/or certification.

The request includes travel expenses for 120 to 150 members who make up the six individual SC advisory committees. Committee membership is primarily made up of representatives of universities, national laboratories, and industry and includes a diverse membership with a balance of disciplines, experiences, and geography. Each of the six advisory committees meets up to three times annually and provides valuable, independent advice to the Department regarding the complex scientific and technical issues that arise in the planning, management, and implementation of the SC programs.

Support Services	**10,567**	**11,141**	**10,262**

Funding is provided for general administrative services and technical expertise provided as part of day-to-day operations, including mailroom operations, travel management, and administration of the Small Business Innovation Research program. Also provided is IT support to include the following: maintenance and operation of SC-HQ Information Management systems and infrastructure; SC-corporate Enterprise Architecture (EA), Capital Planning Investment Control (CPIC), and cyber security management; operation and maintenance of the electronic Portfolio Management Application; and accessibility of DOE's multi-billion dollar R&D program through e-Gov information systems.

Support is provided for the competition of several laboratory contracts to include short-term administrative and technical expertise in the areas of ES&H, S&S, contract and property management, pension planning, etc.

Funding also supports SC strategic planning and analysis activities including: societal and economic impact studies of basic research outcomes; development of methods to assess the SC portfolio, including benchmarking and planning studies; and development of performance metrics and modeling SC impacts on science education/employment trends.

Training and education of federal staff, including continuing education, career development training and other initiatives, such as, the Student Career Experience Program, and the Student Temporary Employment Program will continue to be supported.

	FY 2006	FY 2007	FY 2008
Other Related Expenses	**9,183**	**10,148**	**10,048**

(dollars in thousands)

The request provides support through the Working Capital Fund (WCF) to HQ for office space, utilities, building/equipment maintenance, mail services, LAN connections, supplies, and other services and equipment. Also provided is communications, utilities, building/equipment maintenance, supplies, equipment, and other services at OSTI. SC's funding contribution for operation and maintenance of the STARS and OMB Circular A-123 requirements; IT project management training; and e-Gov initiative fees for E-Travel, Business Gateway, Integrated Acquisition Environment, Geospatial One-Stop, Recruitment One-Stop, Enterprise Human Resources (HR) Initiative, Lines of Business, and Grants.gov is also included.

	FY 2006	FY 2007	FY 2008
Total, Program Direction	**68,155**	**75,045**	**80,741**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Salaries and Benefits	
386 FTEs are supported, an increase of 20 FTEs over FY 2007. This assumes a 2.2% pay raise for 2008 and an increased cap for SES basic pay.	+6,989
Travel	
Overall travel decreases to fund salaries, benefits, and other pay related costs.	-314
Support Services	
Overall support services activities decrease to fund salaries, benefits, and other pay related costs. A reduction to the Automated Data Processing (ADP) and an offsetting increase to the Reports and Analysis Management and General Administrative Services categories reflects realignment of IT activities associated with SC mission applications and services: EA, CPIC, and cyber security.	-879
Other Related Expenses	
Overall other related expenses decrease to fund salaries, benefits, and other pay related costs. A reduction to the Operation and Maintenance of Equipment and offsetting increase to the Equipment categories reflects a realignment of SC IT activities.	-100
Total Funding Change, Program Direction	**+5,696**

Support Services by Category

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Technical Support			
Feasibility of Design Considerations	130	—	—
Development of Specifications	290	304	300
System Definition	140	250	200
System Review and Reliability Analyses	201	627	500
Trade-off Analyses	35	—	—
Test and Evaluation	160	—	—
Total, Technical Support	956	1,181	1,000
Management Support			
Automated Data Processing	7,175	6,710	3,888
Training and Education	293	319	358
Reports and Analyses Management and General Administrative Services	2,143	2,931	5,016
Total, Management Support	9,611	9,960	9,262
Total, Support Services	10,567	11,141	10,262

Other Related Expenses by Category

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Other Related Expenses			
Communications, Utilities, Miscellaneous	368	375	383
Printing and Reproduction	2	2	2
Other Services	1,925	2,335	1,977
Operation & Maintenance of Equipment	972	912	244
Supplies and Materials	289	379	112
Equipment	185	127	1,190
Working Capital Fund	5,442	6,018	6,140
Total, Other Related Expenses	9,183	10,148	10,048

Field Operations

Funding Profile by Category

(dollars in thousands/whole FTEs)

	FY 2006	FY 2007	FY 2008
Chicago Office (CH)			
Salaries and Benefits	20,961	22,008	22,750
Travel	389	320	382
Support Services	1,749	1,867	1,905
Other Related Expenses	1,608	1,967	1,023
Total, Chicago Office	24,707	26,162	26,060
Full Time Equivalents	189	192	187
Oak Ridge Office (OR)			
Salaries and Benefits	29,435	30,061	30,675
Travel	502	680	492
Support Services	5,669	6,080	6,194
Other Related Expenses	6,928	7,431	6,789
Total, Oak Ridge Office	42,534	44,252	44,150
Full Time Equivalents	296	290	282
Ames Site Office (AMSO)			
Salaries and Benefits	422	446	465
Travel	14	15	25
Support Services	29	21	30
Other Related Expenses	27	38	35
Total, Ames Site Office	492	520	555
Full Time Equivalents	3	3	3
Argonne Site Office (ASO)			
Salaries and Benefits	3,091	3,221	3,522
Travel	48	40	41
Support Services	175	230	262
Other Related Expenses	366	322	300
Total, Argonne Site Office	3,680	3,813	4,125
Full Time Equivalents	23	25	25

(dollars in thousands/whole FTEs)

	FY 2006	FY 2007	FY 2008
Berkeley Site Office (BSO)			
Salaries and Benefits	2,785	3,445	3,542
Travel	30	105	105
Support Services	649	345	412
Other Related Expenses	225	346	335
Total, Berkeley Site Office	3,689	4,241	4,394
Full Time Equivalents	21	25	25
Brookhaven Site Office (BHSO)			
Salaries and Benefits	2,976	3,276	3,771
Travel	72	50	62
Support Services	252	156	180
Other Related Expenses	238	161	221
Total, Brookhaven Site Office	3,538	3,643	4,234
Full Time Equivalents	21	25	27
Fermi Site Office (FSO)			
Salaries and Benefits	1,993	2,074	2,197
Travel	42	41	53
Support Services	149	125	146
Other Related Expenses	51	106	100
Total, Fermi Site Office	2,235	2,346	2,496
Full Time Equivalents	15	15	15
New Brunswick Laboratory (NBL)			
Salaries and Benefits	0	0	3,956
Travel	0	0	73
Support Services	0	0	274
Other Related Expenses	0	0	2,341
Total, New Brunswick Laboratory	0	0	6,644
Full Time Equivalents	0	0	35

	FY 2006	FY 2007	FY 2008
	(dollars in thousands/whole FTEs)		
Pacific Northwest Site Office (PNSO)			
Salaries and Benefits	4,247	4,497	4,559
Travel	121	95	63
Support Services	87	135	104
Other Related Expenses	933	826	627
Total, Pacific Northwest Site Office	5,388	5,553	5,353
Full Time Equivalents	35	36	36
Princeton Site Office (PSO)			
Salaries and Benefits	1,430	1,616	1,640
Travel	34	10	39
Support Services	1	—	10
Other Related Expenses	153	42	70
Total, Princeton Site Office	1,618	1,668	1,759
Full Time Equivalents	12	12	12
Stanford Site Office (SSO)			
Salaries and Benefits	1,243	1,703	2,038
Travel	56	53	55
Support Services	153	264	346
Other Related Expenses	173	114	112
Total, Stanford Site Office	1,625	2,134	2,551
Full Time Equivalents	10	13	13
Thomas Jefferson Site Office (TJSO)			
Salaries and Benefits	1,309	1,365	1,671
Travel	76	47	73
Support Services	9	55	91
Other Related Expenses	63	33	37
Total, Thomas Jefferson Site Office	1,457	1,500	1,872
Full Time Equivalents	11	12	12

	(dollars in thousands/whole FTEs)		
	FY 2006	FY 2007	FY 2008
Total Field Operations			
Salaries and Benefits	69,892	73,712	80,786
Travel	1,384	1,456	1,463
Support Services	8,922	9,278	9,954
Other Related Expenses	10,765	11,386	11,990
Total, Field Operations	90,963	95,832	104,193
Full Time Equivalents	636	648	672

Mission

The Field Operations subprogram is the funding source for the SC field Federal workforce. Responsibilities include the Integrated Support Center (ISC) comprised by the Chicago and Oak Ridge Offices' management and administrative functions and the site offices' oversight of Management and Operating contract performance supporting SC laboratories and facilities. These SC laboratories include Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, and Pacific Northwest national laboratories; Ames Laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility. In addition, beginning in FY 2008, SC will support the New Brunswick Laboratory (NBL), a government-owned, government-operated center of excellence in the measurement science of nuclear materials. The NBL is administered through and is a part of the CH Office.

This subprogram supports the field Federal workforce responsible for SC and other DOE programmatic missions performed in support of science and technology, energy research, and environmental management. Centers of Excellence include Grants Management and Intellectual Property Law at CH and the Financial Service Center at OR. Workforce operations include financial stewardship, HR, grants and contracts, labor relations, security, legal counsel, public affairs, 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, and facility and ground maintenance are also included. Services provided through the Department's Working Capital Fund (WCF) include Payroll Processing, the Corporate Human Resource Information System (CHRIS), and training and certification of Project Managers. 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.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Salaries and Benefits	**69,892**	**73,712**	**80,786**

The FY 2008 request supports 672 FTEs in the SC field complex. This is an increase of 24 FTEs over FY 2007 and comprises three parts:

- an increase of 4 additional FTEs to support full staffing of Federal Project Offices at the Brookhaven Site Office and OR Office to ensure sound project implementation and management;
- an increase of 35 additional FTEs at NBL, previously funded by the former SP;
- an offsetting reduction, accomplished by means of attrition and other workforce incentives, of 15 FTEs consistent with the OneSC FTE outyear approach initiated in FY 2006.

The FY 2008 salary and benefit request assumes a 2.2% pay raise in January 2008; increased cap for SES basic pay; and other pay-related costs such as the government's contribution for employee health insurance and retirement.

Travel	**1,384**	**1,456**	**1,463**

Travel enables field staff to work routine operational needs, participate on task teams, and perform contractor oversight at geographically dispersed facilities to ensure implementation of DOE orders and regulatory requirements; e.g., process reviews, internal audits, compliance reviews, oversight of investigations, and administrative proceedings. Funding is also provided for attendance at conferences and training for skill maintenance, certification, etc.

Support Services	**8,922**	**9,278**	**9,954**

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 routine computer maintenance, specific IT improvements, operating systems upgrades, cyber security, network monitoring, firewalls, and disaster recovery tools. Other areas include staffing 24-hour emergency and communications centers, processing/distributing mail, travel management centers, contract close-out activities, copy centers, directives coordination, filing and retrieving records, etc. Training and education of Federal staff are also included.

Other Related Expenses	**10,765**	**11,386**	**11,990**

Day-to-day requirements associated with operating a viable office are funded, including fixed costs associated with occupying office space, utilities, telecommunications, WCF (payroll processing, CHRIS, and Project Manager training), 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, supplies, and building maintenance.

Total, Field Operations	**90,963**	**95,832**	**104,193**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Salaries and Benefits	
672 FTEs are supported, an increase of 24 FTEs from FY 2007; including the NBL workforce (35 FTEs, +$3,956,000) previously funded by the former SP. The increase assumes a 2.2% pay raise for 2008, and an increased pay cap for SES basic pay, and other pay related costs.	+7,074
Travel	
The funding increase includes travel for NBL (+$73,000) previously funded by the former SP. Offsetting reductions fund salaries, benefits, and other pay related costs.	+7
Support Services	
The funding increase is the result of re-negotiations of ADP support services contracts and wage determinations by the Department of Labor; ADP and training in support of the NBL previously funded by the former SP (+$274,000); and incorporating non-pay inflation of 2.4%. An offsetting reduction in training requirements is driven by reduced FTEs at CH and OR and anticipated efficiencies realized through the new consolidated Departmental training services organization.	+676
Other Related Expenses	
The funding increase includes $2,341,000 for NBL previously funded by the former SP. Offsetting reductions fund salaries, benefits, and other pay related costs.	+604
Total Funding Change, Field Operations	**+8,361**

Support Services by Category

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Management Support			
Directives Management Studies	318	328	338
Automated Data Processing	4,407	3,785	4,253
Training and Education	893	876	809
Reports and Analyses Management and General Administrative Services	3,304	4,289	4,554
Total, Support Services	8,922	9,278	9,954

Other Related Expenses by Category

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Other Related Expenses			
Rent to GSA	791	947	946
Rent to Others	660	1,515	796
Communications, Utilities, Miscellaneous	1,382	2,580	2,684
Printing and Reproduction	17	106	25
Other Services	3,925	1,952	3,492
Operation and Maintenance of Equipment	2,267	2,592	1,630
Supplies and Materials	792	523	738
Equipment	487	601	1,079
Working Capital Fund	444	570	600
Total, Other Related Expenses	10,765	11,386	11,990

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Capital Equipment	125	127	—

Workforce Development for Teachers and Scientists

Funding Profile by Subprogram

(dollars in thousands)

	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Workforce Development for Teachers and Scientists			
Undergraduate Research Internships	2,958	3,170	3,070
Graduate/Faculty Fellowships	2,793	6,722	6,576
Pre-College Activities	1,369	1,060	1,354
Total, Workforce Development for Teachers and Scientists	7,120[a]	10,952	11,000

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
The Omnibus Energy Legislation: Sec. 995. Educational Programs in Science and Mathematics amends Public Law 101-510, "DOE Science Education Enhancement Act", 1995
Public Law 109-58, "Energy Policy Act of 2005"

Mission

The mission of the Workforce Development for Teachers and Scientists (WDTS) program is to provide transforming science and technology experiences to the Nation's students and teachers of science, technology, engineering, and mathematics (STEM).

WDTS performs the following functions in support of its overall mission: (1) builds a link between the national laboratories and the science education community by providing funding, guidelines, and evaluation of mentored research experiences at the national laboratories to K–12 teachers and college faculty to enhance their content knowledge and research capabilities; (2) provides mentor-intensive research experiences at the national laboratories for undergraduate and graduate students to inspire commitments to the technical disciplines and to pursue careers in science, technology, engineering, and mathematics thereby helping our national laboratories and the Nation meet the demand for a well-trained scientific/technical workforce; and (3) encourages and rewards middle and high school students across the Nation to share, demonstrate, and excel in math and the sciences, and introduces these students to the national laboratories and the opportunities available to them when they go to college.

Benefits

In order to provide the Nation with the leadership to help guide it to a renewed excellence in science and mathematics education, WDTS has a grade school through graduate school continuum of programs. This is designed to provide students with an uninterrupted pathway to STEM careers. Through this unified program, WDTS can attract, train, and retain the talent needed for the national laboratories to execute the compelling science that the Department of Energy (DOE) conducts and support the Nation's ability to remain a world leader in science and technology.

---

[a] Total is reduced by $72,000 for a rescission in accordance with P.L. 109–148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

WDTS supports three science, technology, and workforce development subprograms that are designed to provide appropriate opportunities at various stages in STEM career paths: (1) Undergraduate Research Internships provide research opportunities for a broad base of undergraduate students planning to enter STEM careers, including teaching; (2) Graduate/Faculty Fellowships for STEM students, teachers, and faculty; and (3) Pre-College Activities for middle and high school students, specifically the Middle and High School National Science Bowls. Each subprogram targets a different group of students and teachers to attract a broad range of participants to the programs and to expand the pipeline of students who will enter the STEM workforce. In this fashion, the subprograms use our national laboratories to meet the Department's needs, as well as a national need, for a well-trained scientific and technical workforce. The program also has a focus on professional development for teachers and faculty who often serve their students as the primary models and inspiration for entering the scientific and technical workforce.

Significant Program Shifts

The Department of Energy Academies Creating Teacher Scientists (DOE ACTS) program, formerly known as the Laboratory Science Teacher Professional Development (LSTPD) program, is a 3-year commitment experience for K–12 teachers and faculty. FY 2008 represents the fifth year of this program and there will be a total of 300 teachers (27 new and 273 continuing). The LSTPD program is renamed to DOE ACTS in response to recommendations from the Education and Workforce Subcommittee of the Secretary of Energy's Advisory Board (SEAB).

Each national laboratory can select to implement either or both of the two types of teacher professional development models in DOE ACTS: (1) Teachers as Investigators (TAI) is geared towards novice teachers typically in the elementary to intermediate grade levels; and (2) Teachers as Research Associates (TARA) for teachers with a stronger background in science, mathematics, and engineering. In FY 2007, 17 national laboratories will participate in this program. Each laboratory in 2006 submitted a proposal that was peer reviewed by a group of external evaluators that included teachers, university professors, and program evaluation experts. The program's overall outcomes are designed to be in line with the No Child Left Behind Act, specifically assisting teachers with becoming highly qualified in their content areas and assessing the direct impact on the quality of teaching and the instruction that students receive.

After the first year of implementation in FY 2004, an external evaluation concluded that this program was a success. Two of the participating laboratories were shown to be premier models in achieving the program's systemic goal to create a cadre of STEM teachers who have the proper content knowledge and scientific research experience coupled with the necessary educational leadership experience to become agents of positive change in their local, regional, and national education communities. These two models were the foundation for the DOE ACTS.

In *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, National Academies, 2005, it states, "This Nation must prepare with great urgency to preserve its strategic and economic security…Recommendation A: Increase America's talent pool by vastly improving K–12 science and mathematics education." *Rising Above the Gathering Storm* also points to summer institutes as a solution to teacher training and for improving the content knowledge of teachers. In the Appendix, it referred to DOE's LSTPD program (now called DOE ACTS) as an example of a teacher training institute.

In the *Final Report of the Secretary of Energy Advisory Board's (SEAB) Science and Mathematics Education Task Force*, May 5, 2006, the committee found that "Teachers—especially middle-school teachers—are crucial for maintaining students' enthusiasm for science and encouraging students to consider science and engineering as careers, yet they are also the most underserved and least prepared by traditional training." The report continues, "DOE's national laboratories have the additional potential to transform science teachers into "scientist-teachers," by allowing them to discover the fascination of participating in authentic scientific investigation, so they thus can excite students with both up-to-date knowledge and personal enthusiasm."

A previous SEAB report stated, "…just as NASA inspires school children with the excitement and beauty of space sciences, just as NIH similarly reaches out to schools to explain the frontiers and the benefits of the life sciences, so should DOE use its vast frontier technological facilities and the collaboration of scientists from all over the world to inspire students and teachers with the rich frontiers of the molecular, atomic, nuclear and sub-nuclear worlds. The Department's laboratories and university programs offer unique resources for mounting aggressive programs to support the Nation's students and teachers in science, mathematics and engineering." Charles M. Vest *et al.*, SEAB Task Force on the Future of Science Programs, *Critical Choices; Science, Energy, and Security,* October 13, 2003.

DOE participated in the Academic Competitiveness Council (ACC) interagency efforts during 2006 to help develop a comprehensive government-wide math and science education and outreach program inventory, review the quality of our program evaluations, collaborate in the development of common goals and performance metrics, and begin implementing changes to improve evaluation and program operations. In winter 2007, the Secretary of Education will transmit to Congress a final report describing the activities of the ACC and setting forth recommendations for improving the effectiveness of Federal science and math education investments.

Undergraduate Research Internships

Funding Schedule by Activity

(dollars in thousands)

	FY 2006	FY 2007	FY 2008
Undergraduate Research Internships			
Science Undergraduate Laboratory Internship	2,447	2,645	2,545
Community College Institute of Science and Technology	283	311	311
Pre-Service Teachers	228	214	214
Total, Undergraduate Research Internships	2,958	3,170	3,070

Description

The goal of the Undergraduate Research Internships subprogram is to continue the Department's long-standing role of providing mentor-intensive research experiences at the national laboratories for undergraduate students to enhance their content knowledge in science and mathematics and their investigative expertise; and to inspire commitments to careers in science, engineering, and K–12 STEM teaching. Through providing a wide variety of college undergraduates the opportunity to work directly with many of the world's best scientists and use the most advanced scientific facilities available, this program will expand the Nation's supply of highly skilled scientists and engineers, especially in the physical sciences where the greatest demand lies because of a steady decline in U.S. citizens entering these fields.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from the subprograms which support the GPRA Units in carrying out their mission. Undergraduate Research Internships perform three functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

The Undergraduate Research Internships subprogram provides a wide diversity of research opportunities for undergraduate students to experience genuine scientific discovery and become a member of the unique scientific culture of the national laboratory community. It also provides the laboratory mentors with a more enriching environment in which to conduct their research.

Supporting Information

The Undergraduate Research Internships subprogram contains three activities. To ensure all participants enjoy the greatest benefit from their participation, clear expectations and benchmarks are designed into all programs. Programs are regularly evaluated and adjustments are made to evolve the programs to the changing needs of the Nation.

The Science Undergraduate Laboratory Internship (SULI) strengthens the students' academic training and introduces them to the unique intellectual and research facility resources present at the national laboratories. Research internships are available during the spring, summer, and fall terms.

The Community College Institute (CCI) of Science and Technology provides a ten-week summer 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.

Pre-Service Teachers (PST) is for undergraduate students who plan on pursuing 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.

FY 2006 Accomplishments

- In 2006, more than 97% of all students in undergraduate research internships submitted abstracts (about 620) and research papers, which were published in the sixth edition of the "Journal of Undergraduate Research." The 15 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 St. Louis, Missouri in February 2006.
- WDTS has upgraded its innovative, interactive Internet system for all SC 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 on-line application system is linked with an SC laboratory central processing center, called Education Link, and allows the students and researchers at the laboratories to select and match in research areas of common interest and includes online submission of research papers, grant requests, and questionnaires. In 2006, the national laboratories' education staffs are completing their self-assessment on-line. The self-assessment provides WDTS with information on how each laboratory implemented the programs that WDTS funds.
- CCI is open to students from all community colleges. In the summer of 2006, 56 community college students, including National Science Foundation funded participants, attended a 10-week mentor-intensive scientific research experience at several DOE national laboratories. About 37% of the participating students came from under-represented groups in STEM disciplines; many were "non-traditional" students. Grades of abstracts for these students were statistically equal to those from the four-year program. Fourteen community college students also participated with faculty members as part of a Faculty and Student Team.
- In 2006, WDTS established a relationship with the National Institutes of Health (NIH) to bring NIH funded students from minority serving institutions into the WDTS undergraduate programs.
- A 3-year NSF "Dear Colleague" letter was signed that continues NSF support of their students in WDTS undergraduate programs, including the Faculty and Student Teams (FaST) program. This letter provides information to the NSF principal investigators on the WDTS programs and the partnership the two agencies have with respect to the undergraduate research internships and FaST programs at the national laboratories. This is the avenue that NSF utilizes to provide funding to the students and faculty that are selected to participate in WDTS programs.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Science Undergraduate Laboratory Internship	**2,447**	**2,645**	**2,545**

Science Undergraduate Laboratory Internship (SULI) supports a diverse group of students at our national laboratories in individually mentored research experiences. Through these unique and highly focused experiences these students are transformed into long-term members of the national laboratory community and become a repository of talent to help the DOE meet its science mission goals. Students in the program: 1) apply on a competitive basis and are matched with mentors working in the student's fields of interest; 2) spend an intensive 10-16 weeks working under the individual mentorship of resident scientists; 3) produce an abstract and research paper; and 4) attend seminars that broaden their view of science careers and help them understand how to become members of the scientific community. Activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys, and an annual evaluation by a group of peers, both within and outside of the DOE. An undergraduate student journal is produced annually that publishes peer-reviewed research papers and all abstracts of students in this activity. Full research papers published in the journal are presented by the student authors at the annual symposium of the American Association for the Advancement of Science (AAAS). The abstracts of these students' and their mentors' works are posted on the AAAS web site. The NSF collaborates with DOE to offer students in its undergraduate student programs access to individually mentored research internships that they would otherwise not have. This activity will ensure a steady flow of students with growing interest in science careers into the Nation's pipeline of workers in both academia and industry. A system is being refined to track students in their academic career paths.

In FY 2006, with DOE, NSF and other leveraged support, 26 students participated in the spring semester program, 377 students participated in the summer, and 21 students participated in the fall semester program. The DOE contribution will support an estimated 355 students in FY 2007 and 340 in FY 2008.

Community College Institute of Science and Technology	**283**	**311**	**311**

Community College Institute of Science and Technology (CCI) is designed to address shortages, particularly at the technician and paraprofessional levels, and will help develop the workforce needed to continue building the DOE's capacity in critical areas for the next century. Since community colleges account for over 40% of the entire Nation's undergraduate enrollment and a majority of under-represented minorities in STEM, this is a clear avenue to increase the numbers of U.S. scientists and engineers. The CCI particularly targets students from under-represented populations in science and technology fields to increase the diversity of the workforce. The CCI provides a ten-week mentored research internship at a DOE national laboratory for highly motivated community college students. Students in the program: 1) apply online and are matched with mentors working in the student's field of interest; 2) spend an intensive ten weeks working under the individual mentorship of resident scientists; 3) produce an abstract and formal research paper; and 4) 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. Activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys, and outside evaluation. An ongoing undergraduate student journal was created to publish selected full research papers and all abstracts of students in this activity. CCI was originally a

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

collaborative effort with DOE, its national laboratories, the American Association of Community Colleges (AACC), and specified member institutions. Through a Memorandum of Understanding with the NSF in FY 2001, undergraduate students in NSF programs (e.g., the Louis Stokes Alliance for Minority Participation and Advanced Technology Education program) are also participating in this activity. This allows NSF's undergraduate programs to include a community college internship in the opportunities they provide to students. The CCI program is now available to students from all community colleges.

In FY 2006, 56 students directly participated in this internship, with an estimated 50 students participating in FY 2007 and the same number of students in FY 2008.

	FY 2006	FY 2007	FY 2008
Pre-Service Teachers	**228**	**214**	**214**

The Pre-Service Teachers (PST) 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 NSF entered into a collaboration with DOE on this activity in FY 2001. This allows NSF's undergraduate pre-service programs to include a PST internship in the opportunities they provide to students. Students in this program: 1) apply on a competitive basis and are matched with mentors working in the student's field of interest; 2) spend an intensive ten weeks working under the mentorship of a master teacher and laboratory scientist to help maximize the building of content knowledge and skills through the research experience; 3) produce an abstract and an educational module related to their research and an optional research paper, poster, or oral presentation; and 4) attend professional enrichment activities, workshops, and seminars that help students apply what they learn to their academic program and the classroom, help them understand how to become members of the scientific community, and improve their communication and other professional skills. Activity goals and outcomes are measured based on students' abstracts, education modules, surveys, and outside evaluation. In FY 2006, PST was hosted at 6 national laboratories with 42 participating students. In FY 2008, the program is flat funded and continues at 4 national laboratories with about 29 students participating, the same as in FY 2007.

	FY 2006	FY 2007	FY 2008
Total, Undergraduate Research Internships	**2,958**	**3,170**	**3,070**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Science Undergraduate Laboratory Internship	
The number of students participating in this program will decrease by 15 in FY 2008, from 355 in FY 2007. Funding is reallocated to support National Science Bowl requirements.	-100

Graduate/Faculty Fellowships

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Graduate/Faculty Fellowships			
DOE Academies Creating Teacher Scientists[a]	1,618	5,645	5,593
Faculty and Student Teams	335	243	243
Albert Einstein Distinguished Educator Fellowship	750	650	650
Energy Related Laboratory Equipment	90	90	90
Faculty Sabbatical Fellowship	—	94	—
Total, Graduate/Faculty Fellowships	2,793	6,722	6,576

Description

The goal of the Graduate/Faculty Fellowships subprogram is to build a link between the resources of the national laboratories and the science education community by providing mentor-intensive research experiences at the national laboratories to students, teachers, and faculty to enhance their content knowledge in science and mathematics and their investigative expertise, to enhance the research capabilities at academic institutions, and to train Instrumentation Specialists in areas of critical need at the national laboratories.

The SC Program Goals will be accomplished not only through the efforts of the direct (GRPA Unit) programs, but with additional efforts from the subprograms which support the GPRA Units in carrying out their mission. Graduate/Faculty Fellowships performs four functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

There are three activities at the graduate level supported in FY 2008 and each provides different benefits, plus the Energy Related Laboratory Equipment activity that grants available excess equipment to institutions of higher education for energy-related research. The Department of Energy Academies Creating Teacher Scientists (DOE ACTS) program will establish long-term relationships between K–12 teachers and the national laboratories. This program was formerly known as Laboratory Science Teacher Professional Development (LSTPD). These teachers will not only improve their content knowledge, but also become authentic partners in the scientific community. As highly trained leaders in STEM education, they will be empowered to reform our Nation’s science education and help to meet the President’s goal of a qualified teacher in every classroom. The Faculty and Student Teams (FaST) program will benefit the individual faculty, their students, and their respective institutions by giving them the training needed to successfully compete for federal science research grants. The Albert Einstein Distinguished Educator Fellowship benefits federal agencies and Congressional offices by these outstanding teachers providing their “real world” classroom expertise and advice. After their fellowship, the teachers go back to their school districts better prepared to be leaders at the local, regional, and

[a] Formerly the Laboratory Science Teacher Professional Development program.

national levels, to be master teachers, and to bring knowledge of federal programs that provide resources to school districts.

Supporting Information

In a survey of STEM graduate students conducted by the NSF, 84% of those surveyed stated that they made their choice to choose a STEM field career by the time they left high school. This suggests that teachers hold the key to increasing the number and quality of the science, technology, and engineering workforce. The President's "No Child Left Behind" initiative has put great emphasis in providing a "qualified teacher in every classroom." In 1999, only 41 percent of U.S. eighth graders received instruction from a math teacher who specialized in math. "About 56% of high school students taking physical science are taught by out-of-field teachers, as are 27% of those taking mathematics. Among schools with high poverty rates, students have a less than 50% chance of getting a science or math teacher who holds both a license and degree in the subject area being taught" (The National Commission on Mathematics and Science Teaching for the 21st Century 1999 citing and Linda Darling-Hammond). Furthermore, the business community is also sounding the alarm at the future of the workforce and the American ability to maintain technological superiority by calling for education reform targeted at teachers. The Business Roundtable, in a report published in July 2005 entitled, "Tapping America's Potential: The Education for Innovation Initiative," calls for the federal government and agencies to, "Support cost-effective professional development [for teachers] and prepare them to teach the content effectively."

The DOE's unique role in teacher training arises from the existence of its national laboratories. The DOE ACTS program is targeted at the Nation's teachers. The primary goal of DOE ACTS is to create a cadre of STEM teachers who have the proper content knowledge and scientific research experience to perform as leaders and agents of positive change in their local and regional education communities. The program has been specifically designed around the best practices in professional development as outlined from educational research and program improvements based upon evaluation data. In developing the program, several models have been considered, including: the National Board Professional Teaching Standards, "Five Core Principles" and Loucks-Horsley and colleagues' "Fifteen Strategies of Professional Development."

DOE ACTS provides K–12 classroom teachers long-term, mentor-intensive professional development through scientific research or research-like opportunities at the national laboratories. The goal of the program is to improve teachers' content knowledge, student achievement in STEM, and numbers of students pursuing STEM careers, and teacher leadership roles in school, district, region, state, and national levels. The outcome is that students will show increased involvement in STEM courses, extracurricular activities, and pursuit of higher level STEM courses and ultimately show rising average scores on standardized tests. Teachers completing the initial laboratory summer experience will be provided monetary support to: help them extend what they have learned to their classes; connect students via classroom activities to ongoing national laboratory research; continue communication and collaboration with other participant teachers and laboratory scientists; take subject enhancement trips to the laboratory; and present their experiences at professional conferences and in publications.

The FaST program provides research opportunities at national laboratories for faculty and undergraduate students from colleges and universities, including community colleges, with limited prior research capabilities as well as institutions serving populations under-represented in the fields of science, technology, engineering, and mathematics, particularly women and minorities. The FaST program supports teams comprised of one faculty member and two to three undergraduate students. The undergraduate students on the FaST teams are funded either by the Science Undergraduate Laboratory

Internship (SULI) or Community College Institute of Science and Technology (CCI) activities. Over a ten-week summer visit to the laboratory, faculty is introduced to new and advanced scientific techniques that contribute to their professional development and help them prepare their students for careers in science, engineering, computer sciences, and technology. 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. The Albert Einstein Distinguished Educator Act of 1994 gives the DOE responsibility for administering this activity of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.

The Energy Related Laboratory Equipment (ERLE) activity grants available excess equipment to institutions of higher education for energy-related research.

FY 2006 Accomplishments

- 17 national laboratories submitted proposals in 2006 to conduct the DOE ACTS in FY 2007. Each proposal was peer reviewed by a panel consisting of teachers, professors, and education program evaluators.
- In FY 2006, WDTS developed, as part of its innovative, interactive Internet system and its central processing center called Education Link, a system to allow teachers to create an on-line electronic portfolio that will include a professional development plan, a survey of content knowledge, and an educational module based on the teacher's research experience at the laboratory. This portfolio will store these materials in snapshots in time during the three years that teachers are involved in DOE ACTS and will be peer-reviewed by external and internal evaluators over time in order to have an independent assessment of the program's impact.
- In 2006, six national laboratories—Argonne, Brookhaven, Lawrence Berkeley, Lawrence Livermore, Oak Ridge, and Pacific Northwest—placed 53 Faculty and Student Teams, with 43 of those being partially supported by the NSF. For summer 2006, there were a total of 172 NSF funded students and faculty that participated on FaST teams. These participants were eligible for supplemental funding from the NSF to pay for their stipends and travel. Since the program began, more than 25 FaST faculty have submitted 62 grant proposals to federal institutions/agencies. A new proposal funded in FY 2006 at the University of Texas El Paso, Super-High Temperature Alloys and Composites from Nb-W-Cr Systems, is a direct product of the FaST experience.
- By leveraging resources and collaborating with other service agencies, the Albert Einstein Distinguished Educator Fellowship activity for FY 2006–2007 placed 17 outstanding K–12 science, math, and technology teachers: 4 in Congressional offices, 2 at the DOE, 2 at the National Aeronautics and Space Administration (NASA), 4 at the NSF, 2 at the NIH, 1 at the National Institute of Standards and Technology (NIST), and 2 at the National Oceanic and Atmospheric Administration (NOAA). In addition, one Fellow was continued at NIH and 2 have continued on in Congressional offices, thus expanding the impact of the Einstein Fellowship.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
DOE Academies Creating Teacher Scientists	**1,618**	**5,645**	**5,593**

DOE ACTS (formerly known as LSTPD) requires a three-year commitment by teachers to participate in this program which is based on research in teacher professional development that indicates that change takes place over an extended period of time and that multi-year professional development is required to make the necessary differences. Each teacher will spend an intensive four to eight weeks annually at the national laboratories 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–12 teachers and adept in both scientific research and scientific writing, will act as liaisons between the mentor scientists and the teacher participants. This will help the teachers transfer the research experiences to their classrooms. Follow-on support is considered critical. Master teachers and other teacher participants receive an $800 per week stipend plus travel and housing expenses.

The National Commission on Mathematics and Science Teaching indicates that professional staff development is one of the most effective ways of improving the achievement of K–12 students. The National Academy of Sciences (NAS) and Teachers Advancement Program (TAP) reports point to teachers as the central players in improving U.S. student STEM achievement. The national laboratories clearly are not positioned to affect the hundreds of thousands of STEM teachers through direct retraining. However, the laboratories can play a pivotal role in reforming the Nation’s STEM education by creating sufficient numbers of highly trained teacher leaders as agents of change in STEM education. This is accomplished by providing carefully designed mentor-intensive training for science and math teachers that will allow them to more effectively teach; to attract their students’ interests to science, mathematics, and technology careers; and to improve student achievement. Teachers apply on a competitive basis and are matched with mentors working in their subject fields of instruction.

All teachers completing the initial summer experience will be provided monetary support each year for the three years they are in the program to purchase materials and scientific equipment, which is critical to transfer their research experiences to their classrooms. In addition, follow-on support will include returning to the laboratory in the first year for additional training sessions of approximately one week, long-term support in following years through communication with other teachers and laboratory scientists, more return trips to the national laboratory, and support to publish or present their work at professional conferences. Evaluation includes a self identification of science content gaps by the teacher participant, successful development of a professional development plan by each teacher, attainment of a leadership role, and impact on local STEM education and student achievement. External evaluation of program effectiveness will include visits to participant teachers’ schools to assess the long-term impact of the program on student achievement. External evaluators submitted a report on the first program year which found that success of this research experience relies on proper placement of each participant to match their professional developmental needs and the follow-on interaction between the teachers and the national laboratories.

The DOE ACTS, which began in FY 2004, funded 103 teachers in FY 2006 (88 continuing from FY 2004 and FY 2005) and will fund 300 teachers in FY 2007 (42 continuing from FY 2005 and FY 2006 and 258 in the new cohort). The FY 2008 request would fund 300 teachers, the same number as

	FY 2006	FY 2007	FY 2008

(dollars in thousands)

FY 2007, with support for 27 new teachers in addition to supporting the 15 teachers that began in FY 2006 and the 258 teachers that began in FY 2007.

Faculty and Student Teams	**335**	**243**	**243**

The Faculty and Student Teams (FaST) summer internship/fellowship provides the opportunity for faculty from colleges and universities with limited prior research capabilities and those institutions serving women or minorities to participate with up to three of their undergraduate students in a mentor-intensive science research project at one of six national laboratories. Faculty members may come back to the laboratory in subsequent summer terms. These faculty members from minority serving institutions have overwhelmingly identified the FaST program as providing a high quality developmental scientific experience. FaST activities at SC laboratories are being conducted in collaboration with the NSF. Faculty from minority serving institutions and other populations under-represented 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. In part because of increasing support from the NSF, the number of teams has increased from 6 in FY 2002 to 53 teams in FY 2006. In FY 2007 and FY 2008, with similar support from NSF, it is projected that there will be about the same number of FaST teams, with 9 fully funded by DOE. FaST is a very productive and over-subscribed activity among the laboratory scientists and faculty members and has enjoyed wide support from the national laboratories. It provides an opportunity for faculty to advance their scientific expertise through a close relationship with a national laboratory.

Albert Einstein Distinguished Educator Fellowship	**750**	**650**	**650**

The Albert Einstein Distinguished Educator 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 Congress and to DOE and other agencies' education and outreach activities. These outstanding teachers provide practical insights and "real world" perspectives to policy makers and program managers. The Einstein Fellowship has been a valuable professional growth opportunity for the teachers, as they return to their education field with knowledge of federal resources and an understanding of national education issues. In FY 2006, with the organizational support of DOE, other federal agencies (including the National Science Foundation, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, National Institutes of Health, and National Institute of Standards and Technology) were able to place 17 teachers as Einstein Fellows. Of these, 5 were directly supported by WDTS (4 fellows in Congress and 1 at DOE). The FY 2008 request will directly support 4 fellows in Congress and 1 at DOE, the same as FY 2007. It will also allow for the continued organizational support for the placement of additional fellows in other federal agencies.

Energy Related Laboratory Equipment	**90**	**90**	**90**

The Energy Related Laboratory Equipment (ERLE) grant activity provides excess equipment to faculty at institutions of higher education for energy-related research. Through the Energy Asset Disposal System, DOE sites identify laboratory equipment that is then listed on the ERLE website, which is maintained by the Office of Scientific and Technical Information and updated several times a week. Colleges and universities can search for equipment of interest to them and apply via the website. DOE property managers approve or disapprove the applications. The equipment is free; the receiving institution pays for shipping costs.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Faculty Sabbatical Fellowship	**—**	**94**	**—**

In FY 2006 the Faculty Sabbatical Fellowship was terminated. Many of the minority serving institutions (MSI's) have indicated that it is difficult to release a faculty member for a year sabbatical, but are encouraging their faculty to participate in the FaST program and bring their students to the national laboratories, ultimately increasing workforce numbers and diversity. Funding requested in FY 2007 will be reallocated to higher priority elements of the WDTS program.

Total, Graduate/Faculty Fellowships	**2,793**	**6,722**	**6,576**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
DOE Academies Creating Teacher Scientists	
The number of teachers participating in DOE ACTS will remain the same in FY 2008 as in FY 2007, but because the number of new teachers selected for the FY 2008 cohort is smaller (27 new teachers compared to 258 new teachers in FY 2007) the laboratory support is reduced slightly.	-52
Faculty Sabbatical Fellowship	
The number of Faculty Sabbaticals for faculty members from MSIs is reduced by 2 (from 2 planned in the FY 2007 request to 0 in FY 2008). The Faculty Sabbatical Fellowship activity was terminated in FY 2006 and the funding requested in FY 2007 will be reallocated after enactment of the FY 2007 appropriation.	-94
Total Funding Change, Graduate/Faculty Fellowships	**-146**

Pre-College Activities

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Pre-College Activities			
National Science Bowl®	1,009	718	918
Middle School Science Bowl	360	342	436
Total, Pre-College Activities	1,369	1,060	1,354

Description

Beyond providing students an opportunity to interact with the scientific community, an additional goal of the Middle and High School Science Bowls is to provide opportunities for students interested in science and math to share and demonstrate their talents outside the classroom in an interactive manner that validates their accomplishments and encourages future science and math studies.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from the subprograms which support the GPRA Units in carrying out their mission. Pre-College Activities performs two functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

These Pre-College Activities introduce middle and high school students to the national laboratory system and the available opportunities they may wish to participate in when they go to college.

Supporting Information

The Pre-College Activities subprogram contains two activities which provide an avenue of enrichment, enlightenment, inspiration, and reward through academic science achievement.

The National Science Bowl® is a prestigious educational event that continues to grow in reputation among students, educators, science coaches, and volunteers as a very important educational event and academic tournament. It is a "grass roots" tournament where over 1,800 high schools from all across the Nation participate in regional events, and each regional event sends a team to the national event. The regional and national events are primarily volunteer programs where several thousand people dedicate weeks of their time to run and judge educational events and be involved with bright, enthusiastic 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. High school teams also design, build, and race hydrogen fuel cell model cars. Since its inception, more than 100,000 high school students have participated in regional tournaments leading up to the national event. At the national event, students meet numerous DOE and non-DOE scientists and are given a rare chance to learn about the wide variety of careers that scientists in all fields pursue.

The Middle School Science Bowl attracts students at one of the most critical stages of their academic development. The emphasis at this grade level is on discovery and hands-on activities such as designing, building, and racing model hydrogen fuel cell cars. Students also solve problems in life and physical sciences and mathematics.

FY 2006 Accomplishments

- 2006 marked the 16th anniversary of the DOE's National Science Bowl®. More than 12,000 high school students were hosted in the 65 regional science bowl events.
- Interactive hands-on activities at the National Science Bowl® were included for the first time. The interactive discovery activities are designed to test the team's ability to actually "do" science in the way that scientists and engineers do. For example; in "Hitting the Target" teams had to roll the marble and hit the center of the target in one try by placing the "target" where the ball will land**.** They did this by creating a simulation where the hill is the inclined plane, the table is the flat portion, a steel ball the boulder, the table is the "drop", and a paper target represents the car. Teams were required to provide qualitative and quantitative documentation as to their problem solving process and rationale.
- The Middle School Science Bowl, initiated in FY 2002 with 8 teams, expanded to 27 regional events with 28 teams traveling to the nationals in FY 2006. The national event was hosted by the National Renewable Energy Laboratory at the University of Denver in Denver, Colorado.
- During FY 2006, nineteen teacher workshops at regional MSSB sites were held to explain and demonstrate the design and construction of fuel cell model cars, and a Teacher Workshop summit was held on best practices for teaching and disseminating information on fuel cells.
- Saturday science seminars at the National Science Bowl® weekend continued, introducing students to many contemporary issues and findings in contemporary scientific research. In FY 2006, two of the speakers were former science bowl participants who have graduated and are launched into their science careers.
- In FY 2006, 16 of the 65 teams took part in designing, building, and racing cars under the Hydrogen Fuel Cell Model Car Challenge that was added to National Science Bowl® in FY 2003. Eight of these teams raced in the stock category and the other eight in the hill climb. Awards were presented to the top teams in this event.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
National Science Bowl®	**1,009**	**718**	**918**

The National Science Bowl® is a nationally recognized, prestigious academic event for high school students. It has attained its level of recognition and participation through a grass-roots design which engenders volunteer participation of professional scientists, engineers, and educators from across the Nation. The students answer questions on topics in astronomy, biology, chemistry, mathematics, and physics. Since 1991, the National Science Bowl® has encouraged 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 recognition for their talent and hard work by solving both traditional academic problems in all fields of science and math in addition to their activity in various hands-on science challenges. The National Science Bowl® includes a day of scientific seminars, a set of model car competitions based upon the hydrogen economy of the future, and an academic competition. Students participating in the National Science Bowl® are tracked to determine the

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

impact on their academic and career choices, including participation in DOE Undergraduate Research Internships.

The regional and national events are primarily volunteer programs where thousands of people dedicate weeks of their time to organize and execute educational events and be involved with bright, enthusiastic high school students. WDTS funding provides all of the travel and lodging expenses for each winning team and seminar speaker to attend the National event, trophies and other awards, and items for the teams to participate in the various hands-on activities and events (e.g. fuel cell car kits, equipment for the interactive science activities, etc.).

The number of regional events remains relatively constant from one year to the next with 64 to 67 teams participating each year. In FY 2008 support for the National Science Bowl is increased by $200,000 to reflect cost increases in areas such as travel, lodging, activities, and speakers.

Middle School Science Bowl	**360**	**342**	**436**

It is well recognized that the middle school years are one of the most productive times to exert an effort to attract and retain student interest in science and math. There are two events at the Middle School Science Bowl: an academic event in mathematics and science, and an activity to design, build and race hydrogen fuel cell model cars. The academic competition is a fast-paced question and answer format where students solve problems about earth, life, physical, and general sciences and mathematics. The model hydrogen fuel cell car competition challenges students to design, build, and race model hydrogen fuel cell cars in order to help them understand the future energy challenges that our Nation is facing. Students who win in regional events 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. The inspiration students receive by interacting with scientists and engineers at this age can positively impact them and be a transforming experience at this critical juncture of their lives and inspire them into STEM careers.

The number of regional events remains relatively constant from one year to the next with 28 to 31 teams participating each year.

Total, Pre-College Activities	**1,369**	**1,060**	**1,354**

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
National Science Bowl	
Funding reflects cost increases in areas such as travel, lodging, activities, and speakers.	+200
Middle School Science Bowl	
The increase provides for slight increases in organizational costs.	+94
Total Funding Change, Pre-College Activities	**+294**

Safeguards and Security

Funding Profile by Subprogram

(dollars in thousands)

	FY 2006 Current Appropriation	FY 2007 Request	FY 2008 Request
Safeguards and Security			
Protective Forces	31,292	33,050	33,050
Security Systems	8,038	6,615	6,615
Information Security	3,784	3,331	3,331
Cyber Security	15,876	18,070	18,070
Personnel Security	4,815	5,725	5,725
Material Control and Accountability	2,392	2,341	2,341
Program Management	7,433	7,460	7,460
Subtotal, Safeguards and Security	73,630	76,592	76,592
Less Security Charge for Reimbursable Work	-5,605	-5,605	-5,605
Total, Safeguards and Security	68,025[a]	70,987	70,987

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 103-62, "Government Performance and Results Act of 1993"
Public Law 109-58, "Energy Policy Act of 2005"

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.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA unit) programs, but with additional efforts from programs which support the GPRA units in carrying out their mission. The Safeguards and Security program performs the following function in support of the overall SC mission: providing protection of employees, facilities, and systems in a manner consistent with the security conditions.

Benefits

The benefit of the Safeguards and Security program is that it provides sufficient protection of DOE assets and resources, thereby allowing the programmatic missions of the Department to be conducted in an environment that is secure based on the unique needs of each site. This Integrated Safeguards and Security Management strategy encompasses a graded approach that enables each facility to design its security protection program to meet the facility-specific threat scenario.

---

[a] Total is reduced by $687,000 for a rescission in accordance with P.L. 109-148, the Emergency Supplemental Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

The following is a brief description of the types of activities performed:

Protective Forces

The Protective Forces activity provides for security guards or security police officers and equipment, training and maintenance needed to effectively carry out the protection tasks during normal and increased or emergency security conditions (SECON). This request is adequate for up to 60 days of heightened security at the SECON 2 level.

Security Systems

The Security Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware include fences, barriers, lighting, sensors, entry control devices, etc.

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. This involves perimeter protection, intrusion detection, firewall protection and user authentication. Cyber security also includes enhancements in network traffic logging and monitoring, risk assessments, and improvements in incident response. It provides for the development of virtual private networks and added security for remote login and wireless connections.

Personnel Security

The Personnel Security activity includes security clearance programs, employee security education, and visitor control. The newly implemented Personal Identity Verification (PIV) program is also conducted under the Personnel Security activity. Employee education and awareness is accomplished through initial, refresher, and termination briefings, 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 of personnel for assessing the amounts of material involved in packaged items, process systems, and wastes. Additionally, this activity provides the programmatic mechanism to ensure that theft, diversion, or operational loss of special nuclear material does not occur. Also included is protection for on- and off-site transport of special nuclear materials.

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, training, planning, and integration of security activities into facility operations.

Detailed Justification

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Ames Laboratory	**607**	**570**	**670**

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation, and oversight in the areas of protective forces, security systems, cyber security, personnel security, material control and accountability, and program management. A protective force is maintained to provide protection of personnel, equipment, and property from acts of theft, vandalism, and sabotage through facility walk-through, monitoring of electronic alarm systems, and emergency communications. Reimbursable work is included in the numbers above in the amount of $26,000.

Argonne National Laboratory	**8,570**	**8,462**	**8,462**

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 protective forces, security systems, information security, cyber security, personnel security, material control and accountability, and program management. These activities ensure that the facility, personnel, and assets remain safe from potential threats. Reimbursable work is included in the numbers above in the amount of $388,000.

Brookhaven National Laboratory	**11,229**	**10,967**	**10,967**

The Brookhaven National Laboratory (BNL) Safeguards and Security program activities are focused on protective forces, security systems, information security, cyber security, personnel security, material control and accountability, and program management. BNL operates a transportation division to move accountable nuclear materials around the site. Material control and accountability efforts focus on accurately accounting for and protecting the site’s special nuclear materials. Reimbursable work is included in the numbers above in the amount of $806,000.

Fermi National Accelerator Laboratory	**3,043**	**3,221**	**3,221**

The Fermi National Accelerator Laboratory Safeguards and Security program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility. Other Safeguards and Security program functions include security systems, cyber security, material control and accountability, and program management.

Lawrence Berkeley National Laboratory	**4,743**	**4,981**	**4,981**

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, material control and accountability of special nuclear material, and program management. Reimbursable work is included in the numbers above in the amount of $830,000.

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Oak Ridge Institute for Science and Education	**1,359**	**1,489**	**1,489**

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection/protective force services by employing unarmed security officers. Program activities include security systems, information security, cyber security, personnel security, and program management. 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. Since the inventory is static, it is accounted for under program management. Reimbursable work is included in the numbers above in the amount of $319,000.

Oak Ridge National Laboratory	**9,219**	**8,396**	**8,396**

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. Protective force resources for ORNL, including those to protect the national U233 Vault at Building 3019, are funded within the Oak Ridge Office. Program planning functions at the laboratory provide for short- and long-range strategic planning, and site safeguards and security plans associated with both the protection of security interests and preparations for contingency operations. Reimbursable work is included in the numbers above in the amount of $1,945,000.

Oak Ridge Office	**15,981**	**17,635**	**17,635**

The Oak Ridge Office Safeguards and Security program provides for contractor protective forces for ORNL, including protection of a Category I special nuclear material facility, Building 3019 ($12,304,000). In addition, protective forces are provided for the Federal Office Building complex, and other activities including security systems, information security, cyber security, and personnel security are supported.

Office of Scientific and Technical Information	**305**	**340**	**340**

The Office of Scientific and Technical Information's mission is to collect, preserve, disseminate, and leverage the scientific and technical information resources of DOE to expand the knowledge base of science and technology and facilitate scientific discovery and application. Safeguards and Security program activities include protective forces, security systems, cyber security, and program management.

Pacific Northwest National Laboratory	**10,285**	**10,993**	**10,993**

The Pacific Northwest National Laboratory (PNNL) Safeguards and Security program consists of physical security systems, information security, cyber security, personnel security, material control and accountability, and program management. These program elements work together in conjunction with a counterintelligence program and an export control program to ensure appropriate protection and control of laboratory assets while ensuring that PNNL remains appropriately accessible to visitors for technical collaboration. Funding for protective force operations remains the responsibility of the Office of Environmental Management. Reimbursable work is included in the numbers above in the amount of $1,222,000.

Princeton Plasma Physics Laboratory	**1,919**	**1,953**	**2,053**

The Princeton Plasma Physics Laboratory Safeguards and Security program provides for protection of government property and other vital assets from unauthorized access, theft, diversion, sabotage, or other

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008

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. Program activities include protective forces, security systems, cyber security, and program management. Reimbursable work is included in the numbers above in the amount of $54,000.

Stanford Linear Accelerator Center	**2,377**	**2,437**	**2,437**

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 protective forces and cyber security program elements. Reimbursable work is included in the numbers above in the amount of $15,000.

Thomas Jefferson National Accelerator Facility	**1,231**	**1,311**	**1,311**

The 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 security systems, cyber security, and program management.

All Other	**2,762**	**3,837**	**3,637**

Funding supports the continuation and management of a consistent cyber security approach across the Office of Science laboratory complex, and other safeguards and security program management needs.

Subtotal, Safeguards and Security	**73,630**	**76,592**	**76,592**
Less Security Charge for Reimbursable Work	**-5,605**	**-5,605**	**-5,605**
Total, Safeguards and Security	**68,025**	**70,987**	**70,987**

Detailed Funding Schedule

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Ames Laboratory			
Protective Forces	152	152	152
Security Systems	40	40	40
Cyber Security	337	300	400
Personnel Security	33	33	33
Material Control and Accountability	5	5	5
Program Management	40	40	40
Total, Ames Laboratory	607	570	670
Argonne National Laboratory			
Protective Forces	3,000	3,000	3,000
Security Systems	944	744	744
Information Security	350	350	350
Cyber Security	1,598	1,840	1,840
Personnel Security	1,070	1,070	1,070

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Material Control and Accountability	980	830	830
Program Management	628	628	628
Total, Argonne National Laboratory	8,570	8,462	8,462
Brookhaven National Laboratory			
Protective Forces	5,654	5,999	5,999
Security Systems	1,383	939	939
Information Security	656	527	527
Cyber Security	2,109	2,170	2,170
Personnel Security	335	234	234
Material Control and Accountability	392	498	498
Program Management	700	600	600
Total, Brookhaven National Laboratory	11,229	10,967	10,967
Fermi National Accelerator Laboratory			
Protective Forces	1,831	1,781	1,781
Security Systems	382	382	382
Cyber Security	672	900	900
Material Control and Accountability	38	38	38
Program Management	120	120	120
Total, Fermi National Accelerator Laboratory	3,043	3,221	3,221
Lawrence Berkeley National Laboratory			
Protective Forces	1,798	1,578	1,578
Security Systems	460	790	790
Cyber Security	1,877	2,020	2,020
Personnel Security	69	9	9
Material Control and Accountability	24	14	14
Program Management	515	570	570
Total, Lawrence Berkeley National Laboratory	4,743	4,981	4,981
Oak Ridge Institute for Science and Education			
Protective Forces	267	314	314
Security Systems	100	102	102
Information Security	143	142	142
Cyber Security	410	520	520
Personnel Security	118	100	100
Program Management	321	311	311
Total, Oak Ridge Institute for Science and Education	1,359	1,489	1,489

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Oak Ridge National Laboratory			
Security Systems	3,199	2,466	2,466
Information Security	369	346	346
Cyber Security	2,160	2,290	2,290
Personnel Security	1,241	1,145	1,145
Material Control and Accountability	434	458	458
Program Management	1,816	1,691	1,691
Total, Oak Ridge National Laboratory	9,219	8,396	8,396
Oak Ridge Office			
Protective Forces	14,998	16,644	16,644
Security Systems	228	157	157
Information Security	463	105	105
Cyber Security	—	350	350
Personnel Security	292	379	379
Total, Oak Ridge Office	15,981	17,635	17,635
Office of Scientific and Technical Information			
Protective Forces	15	15	15
Security Systems	30	30	30
Cyber Security	235	270	270
Program Management	25	25	25
Total, Office of Scientific and Technical Information	305	340	340
Pacific Northwest National Laboratory			
Security Systems	1,073	830	830
Information Security	1,803	1,861	1,861
Cyber Security	2,480	2,110	2,110
Personnel Security	1,657	2,755	2,755
Material Control and Accountability	519	498	498
Program Management	2,753	2,939	2,939
Total, Pacific Northwest National Laboratory	10,285	10,993	10,993
Princeton Plasma Physics Laboratory			
Protective Forces	955	975	975
Security Systems	33	33	33
Cyber Security	586	620	720
Program Management	345	325	325
Total, Princeton Plasma Physics Laboratory	1,919	1,953	2,053

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
Stanford Linear Accelerator Center			
Protective Forces	1,797	1,897	1,897
Security Systems	64	—	—
Cyber Security	516	540	540
Total, Stanford Linear Accelerator Center	2,377	2,437	2,437
Thomas Jefferson National Accelerator Facility			
Protective Forces	695	695	695
Security Systems	102	102	102
Cyber Security	360	440	440
Program Management	74	74	74
Total, Thomas Jefferson National Accelerator Facility	1,231	1,311	1,311
All Other			
Protective Forces	130	—	—
Cyber Security	2,536	3,700	3,500
Program Management	96	137	137
Total, All Other	2,762	3,837	3,637
Subtotal, Safeguards and Security	73,630	76,592	76,592
Less Security Charge for Reimbursable Work	-5,605	-5,605	-5,605
Total, Safeguards and Security	68,025	70,987	70,987

Explanation of Funding Changes

	FY 2008 vs. FY 2007 ($000)
Ames Laboratory	
The increase in cyber security will improve tool sets and firewalls and provide some additional funds to protect personal identifiable information on the site's network.	+100
Princeton Plasma Physics Laboratory	
The increase in cyber security will improve tool sets and firewalls and provide some additional funds to protect personal identifiable information on the site's network.	+100
All Other	
The decrease in FY 2008 headquarters funding represents an increased allocation of cyber security funding to SC Laboratories.	-200
Total Funding Change, Safeguards and Security	—

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2006	FY 2007	FY 2008
General Plant Projects	1,278	—	—
Capital Equipment	223	—	—
Total, Capital Operating Expenses	1,501	—	—