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The Department of Energy's FY 2007 Congressional Budget justification is available on the Office of Chief Financial Offier/CFO homepage at http://www.mbe.doe.gov/budget/

Department of Energy
Appropriation Account Summary
(dollars in thousands - OMB Scoring)

	FY 2005 Current Approp.	FY 2006 Current Approp.	FY 2007 Congressional Request	FY 2007 vs. FY 2006 $	FY 2007 vs. FY 2006 %
Discretionary Summary By Appropriation					
Energy And Water Development, And Related Agencies					
Appropriation Summary:					
Energy Programs					
Energy supply and Conservation	1,801,815	1,812,627	1,923,361	+110,734	+6.1%
Fossil energy programs					
Clean coal technology	-160,000	-20,000	——	+20,000	+100.0%
Fossil energy research and development	560,852	592,014	469,686	-122,328	-20.7%
Naval petroleum and oil shale reserves	17,750	21,285	18,810	-2,475	-11.6%
Elk Hills school lands fund	36,000	84,000	——	-84,000	-100.0%
Strategic petroleum reserve	126,710	207,340	155,430	-51,910	-25.0%
Northeast home heating oil reserve	4,930	——	4,950	+4,950	N/A
Strategic petroleum account	43,000	-43,000	——	+43,000	+100.0%
Total, Fossil energy programs	629,242	841,639	648,876	-192,763	-22.9%
Uranium enrichment D&D fund	495,015	556,606	579,368	+22,762	+4.1%
Energy information administration	83,819	85,314	89,769	+4,455	+5.2%
Non-Defense environmental cleanup	439,601	349,687	310,358	-39,329	-11.2%
Science	3,635,650	3,596,391	4,101,710	+505,319	+14.1%
Nuclear waste disposal	343,232	148,500	156,420	+7,920	+5.3%
Departmental administration	128,598	128,519	128,825	+306	+0.2%
Inspector general	41,176	41,580	45,507	+3,927	+9.4%
Total, Energy Programs	7,598,148	7,560,863	7,984,194	+423,331	+5.6%
Atomic Energy Defense Activities					
National nuclear security administration:					
Weapons activities	6,625,542	6,369,597	6,407,889	+38,292	+0.6%
Defense nuclear nonproliferation	1,507,966	1,614,839	1,726,213	+111,374	+6.9%
Naval reactors	801,437	781,605	795,133	+13,528	+1.7%
Office of the administrator	363,350	338,450	386,576	+48,126	+14.2%
Total, National nuclear security administration	9,298,295	9,104,491	9,315,811	+211,320	+2.3%
Environmental and other defense activities:					
Defense environmental cleanup	6,800,848	6,130,447	5,390,312	-740,135	-12.1%
Other defense activities	687,149	635,578	717,788	+82,210	+12.9%
Defense nuclear waste disposal	229,152	346,500	388,080	+41,580	+12.0%
Total, Environmental & other defense activities	7,717,149	7,112,525	6,496,180	-616,345	-8.7%
Total, Atomic Energy Defense Activities	17,015,444	16,217,016	15,811,991	-405,025	-2.5%
Power marketing administrations:					
Southeastern power administration	5,158	5,544	5,723	+179	+3.2%
Southwestern power administration	29,117	29,864	31,539	+1,675	+5.6%
Western area power administration	171,715	231,652	212,213	-19,439	-8.4%
Falcon & Amistad operating & maintenance fund	2,804	2,665	2,500	-165	-6.2%
Colorado River Basins	——	-23,000	-23,000	——	——
Total, Power marketing administrations	208,794	246,725	228,975	-17,750	-7.2%
Federal energy regulatory commission	——	——	——	——	——
Subtotal, Energy And Water Development and Related Agencies	24,822,386	24,024,604	24,025,160	+556	+0.0%
Uranium enrichment D&D fund discretionary payments	-459,296	-446,490	-452,000	-5,510	-1.2%
Excess fees and recoveries, FERC	-18,452	-15,542	-16,405	-863	-5.6%
Total, Discretionary Funding	**24,344,638**	**23,562,572**	**23,556,755**	**-5,817**	**-0.0%**

Science

Science

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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 **[**forty-seven**]** *forty-nine* passenger motor vehicles for replacement only, including not to exceed one ambulance and two buses, **[**$3,632,718,000**]** *$4,101,710,000*, to remain available until expended. *(Energy and Water Development Appropriations Act, 2006.)*

Explanation of Change

Changes are proposed to reflect the FY 2007 funding and vehicle request.

Science
Office of Science

Overview

Appropriation Summary by Program

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Science					
Basic Energy Sciences	1,083,616	1,146,017	-11,460[a]	1,134,557	1,420,980
Advanced Scientific Computing Research	226,180	237,055	-2,371[a]	234,684	318,654
Biological and Environmental Research	566,597	585,688	-5,857[a]	579,831	510,263
High Energy Physics	722,906	723,933	-7,239[a]	716,694	775,099
Nuclear Physics	394,549	370,741	-3,707[a]	367,034	454,060
Fusion Energy Sciences	266,947	290,550	-2,906[a]	287,644	318,950
Science Laboratories Infrastructure	37,498	42,105	-421[a]	41,684	50,888
Science Program Direction	154,031	160,725	-1,607[a]	159,118	170,877
Workforce Development for Teachers and Scientists	7,599	7,192	-72[a]	7,120	10,952
Safeguards and Security	72,773	74,317	-687[a]	73,630	76,592
Small Business Innovation Research/ Small Business Technology Transfer	113,621[b]	—	—	—	—
Subtotal, Science	3,646,317	3,638,323	-36,327	3,601,996	4,107,315
Less use of prior year balances	-5,062	—	—	—	—
Less security charge for reimbursable work	-5,605	-5,605	—	-5,605	-5,605
Total, Science	3,635,650	3,632,718	-36,327	3,596,391	4,101,710

Preface

As part of the President's American Competitiveness Initiative, the Office of Science (SC) request for Fiscal Year (FY) 2007 is $4,101,710,000; an increase of $505,319,000, or 14.1%, from the FY 2006 appropriation. The request funds investments in basic research that are critical to both the future economic competitiveness of the United States and to the success of Department of Energy (DOE) missions in national security and energy security; advancement of the frontiers of knowledge in the physical sciences and areas of biological, environmental, and computational sciences; and provision of world-class research facilities for the Nation's science enterprise.

SC provides the basic research that underpins the Department's technically complex missions. Part of this support is in the form of large-scale scientific user facilities that form the backbone of modern research. The suite of forefront facilities includes the world's highest energy proton accelerator—Fermi National Accelerator Laboratory's (Fermilab's) Tevatron—and the soon to be operational Spallation

[a] Reflects a rescission in accordance with P.L. 109–148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.
[b] Includes $77,842,000 reprogrammed within SC and $35,779,000 transferred from other DOE programs.

Neutron Source (SNS). SC facilities represent a continuum of unique capabilities that meet the needs of a diverse set of nearly 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.

Within the Science appropriation, SC has 10 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).

This Overview will describe Strategic Context, Mission, Benefits, Strategic Goals, and Funding by General Goal. These items together put the appropriation request in perspective. The Annual Performance Results and Targets, Means and Strategies, and Validation and Verification sections address how the goals will be achieved and how performance will be measured. Finally, this Overview will address the Research and Development (R&D) Investment Criteria, Program Assessment Rating Tool (PART), and Significant Program Shifts.

Strategic Context

Following publication of the Administration's National Energy Policy, the Department developed a Strategic Plan that defines its mission, four strategic goals for accomplishing that mission, and seven general goals to support the strategic goals. Each appropriation has developed quantifiable goals to support the general goals. Thus, the "goal cascade" is the following:

Department Mission ➡ Strategic Goal (25 yrs) ➡ General Goal (10–15 yrs) ➡ Program Goal (Government Performance and Results Act [GPRA] Unit) (10–15 yrs).

To provide a concrete link between budget, performance, and reporting, the Department developed a "GPRA Unit" concept. Within DOE, a GPRA Unit defines a major activity or group of activities that support the core mission and aligns resources with specific goals. Each GPRA Unit has completed or will complete a PART. A unique program goal was developed for each GPRA unit. A numbering scheme has been established for tracking performance and reporting.

The goal cascade accomplishes two things. First, it ties major activities for each program to successive goals and, ultimately, to DOE's mission. This helps ensure the Department focuses its resources on fulfilling its mission. Second, the cascade allows DOE to track progress against quantifiable goals and to tie resources to each goal at any level in the cascade. Thus, the cascade facilitates the integration of budget and performance information in support of the GPRA and the President's Management Agenda (PMA).

Another important component of our strategic planning—and the PMA—is use of the Administration's R&D investment criteria to plan and assess programs and projects. The criteria were developed in 2001 and further refined with input from agencies, Congressional staff, the National Academy of Sciences, and numerous private sector and nonprofit stakeholders.

The chief elements of the R&D investment criteria are quality, relevance, and performance. Programs must demonstrate fulfillment of these elements. For example, to demonstrate relevance, programs are expected to have complete plans with clear goals and priorities. To demonstrate quality, programs are expected to commission periodic independent expert reviews. There are several other requirements, many of which R&D programs have and continue to undertake.

An additional set of criteria were established for R&D programs developing technologies that address industry issues. Some key elements of the criteria include: the ability of the programs to articulate the appropriateness and need for Federal assistance; relevance to the industry and the marketplace; identification of a transition point to industry commercialization (or of an off-ramp if progress does not meet expectations); and the potential public benefits, compared to alternative investments, that may accrue if the technology is successfully deployed.

The Office of Management and Budget (OMB)-Office of Science and Technology Policy (OSTP) guidance memorandum to agencies (http://www.ostp.gov/html/budget/2007/ostp_omb_guidancememo_FY07.pdf) describes the R&D investment criteria and identifies steps agencies should take to fulfill them. Where appropriate, throughout these justification materials, specific R&D investment criteria and requirements are cited to explain the Department's allocation of resources.

Mission

SC's mission is to deliver the 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

Developments at the nanoscale are expected to make major contributions to meeting DOE's applied mission needs such as strong, tough, ductile, lightweight materials with low failure rates that will improve the fuel efficiency and safety of ground and air transportation; smart materials that will range from paints that change color with temperature to windows that respond to thermal inputs and improve energy efficiency; nanostructured catalysts that will lead to cleaner, less expensive, more environmentally friendly petroleum refining; better batteries and fuel cells; improved chemical and product manufacturing; and innovative systems for harvesting light and storing energy that will dramatically improve solar energy conversion.

The knowledge developed from the Genomics: GTL program on understanding microbial genes and protein complexes, their regulation, and their functional roles in an ecosystem can lead both to greater energy security and a stabilization of net atmospheric CO_2 emissions. Currently, petroleum refineries "crack" raw oil through heat and catalysis to create gasoline and other petroleum products. In the future, we envision biorefineries that, in a one-step process, use microbial cellulase enzymes to crack the complex cellulose and hemicellulose in plant walls into simple sugars and microbially ferment those sugars into ethanol and other biobased products. Genomics: GTL research findings can accelerate this vision by improving the understanding of both plant cell-wall construction and the microbial enzymes necessary to deconstruct those walls. Microbes could also enable the inexpensive production of hydrogen by consuming a hydrogenated feedstock and releasing hydrogen. In addition, plants use the sun's energy to convert atmospheric carbon dioxide to biomass (e.g., leaves, roots, stems, and seeds) composed mainly of cellulose and lignin. Some biomass ultimately becomes incorporated into the soil where its carbon may be sequestered for hundreds of years. Understanding plant genes, their regulation and the role of microbes in the plant's root zone ultimately will enable manipulation of their carbon storage processes. Specialized, large-scale user facilities are needed to achieve the necessary economies of scale and output of molecular data associated with the Genomes: GTL effort.

Through investments in HEP and NP, 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. This knowledge rapidly travels from scientific journals to textbooks where it informs the creative vision of scientists, engineers, and entrepreneurs. This final path is neither linear nor overt, but we know that understanding the laws of nature is the key to technological progress. With this request, SC will focus efforts in these areas to places of world leadership and experiments with the greatest potential for radical discovery. The Relativistic Heavy Ion Collider (RHIC) will continue to explore new states of matter recently discovered there, providing a direct probe of the conditions found in exotic locations of the universe and at the first moments of the birth of the universe. Significant advances will be made in nuclear structure and nuclear astrophysics with the study of energy production in stars, the formation of heavy elements, and explosive stellar events. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) provides unique world-wide capabilities in polarized electron beam studies of the quark structure of the nucleon—it is the world's most powerful electron "microscope" for studying the nucleus with unprecedented resolving power. The Fermilab Tevatron, the world's highest energy accelerator, is turning its powerful beams to solve the mystery of the existence of mass, to find the first evidence of a supersymmetric universe, and to explore the distinct possibility of finding extra dimensions of space and time in which we live. The B-factory at the Stanford Linear Accelerator Center (SLAC) is providing precision measurements of how matter and antimatter behave differently in the decays of short-lived exotic particles known as B-mesons, considered by physicists to be vital to understanding why the whole universe appears to be predominantly matter, rather than an equal quantity of matter and antimatter. There is also a broad program of experiments that studies those aspects of the fundamental nature of particles, forces, and the universe that cannot be determined solely through the use of accelerators, including the search for or measurement of dark matter and dark energy. A recent example is the unexpected and significant finding that neutrinos have mass, discovered by studying solar and cosmic ray neutrinos.

Strategic, General, and Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the mission) plus seven general goals that tie to the strategic goals. The Science appropriation supports the following goal:

Science Strategic Goal: To protect our national and economic security by providing world-class scientific research capacity and advancing scientific knowledge.

General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

The programs funded by the Science appropriation have the following six Program Goals which contribute to General Goal 5 in the "goal cascade":

Program Goal 05.22.00.00: 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.

Program Goal 05.23.00.00: 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.

Program Goal 05.21.00.00: 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.

Program Goal 05.19.00.00: 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.

Program Goal 05.20.00.00: 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.

Program Goal 05.24.00.00: 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 General Goals

Six of the programs within the Science appropriation directly contribute to General Goal 5 as follows:

BES contributes to General Goal 5 by advancing science through atomic- and molecular-level studies in materials sciences and engineering, chemistry, geosciences, and energy biosciences. 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 micro-characterization centers. These facilities provide outstanding capabilities for imaging and characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological samples. Construction of the Spallation Neutron Source will be completed during the 3rd quarter of FY 2006 and will join the suite of BES scientific user facilities. Four Nanoscale Science Research Centers will begin their first full year of operation in FY 2007—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, and the Center for Integrated Nanotechnologies at Sandia National Laboratories and Los Alamos National Laboratory. A fifth Center, the Center for Functional Nanomaterials at Brookhaven National Laboratory, will be in its final year of construction. The Linac Coherent Light Source (LCLS) at Stanford Linear Accelerator Center is fully funded in FY 2007, including partial support for the SLAC linac. The Transmission Electron Aberration Corrected Microscope project continues as a Major Item of Equipment (MIE). Support is provided for 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 and will continue ongoing Scientific Discovery through Advanced Computing (SciDAC) efforts.

The ASCR program contributes to General Goal 5 by advancing mathematics and computer science, and developing the specialized algorithms, the scientific software tools, and the software libraries needed by DOE researchers to effectively use high-performance computing and networking hardware for scientific discovery. The ASCR program has been a leader in the computational sciences for several decades and has been acknowledged for pioneering accomplishments. The Leadership Computing activity will be expanded to Argonne National Laboratory to provide up to 100 teraflops of high performance computing capability with low electrical power needs to advance 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 be upgraded to deliver 250 teraflops of peak capability in FY 2007. In FY 2007, the Energy Science Network (ESnet) will deliver a backbone network with two to four times the capability of today's network, to support the science mission of the Department. A procurement is planned in FY 2006 for the next generation of high performance resources at the National Energy Research Scientific Computing Center (NERSC) to be delivered in early FY 2007. This NERSC-5 system is expected to provide 100–150 teraflops of peak computing capacity. Corresponding investments in research and evaluation prototypes will help prepare scientists for petascale computing. ASCR will also continue core research efforts in applied mathematics and computer science and expand efforts in the SciDAC program and institutes.

BER contributes to General Goal 5 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 or make hydrogen; by developing models to predict climate over decades to centuries; by developing science-based methods for cleaning up environmental contaminants; by providing regulators with a stronger scientific basis for developing future radiation protection standards; and by conducting limited research in medical imaging, radiopharmaceuticals, and development of an artificial retina. In FY 2007, BER will continue the Genomics: GTL program as a 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. 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 pivotal partner in the interagency Climate Change Science Program focusing on the principal uncertainties of the causes and effects of climate change, the global carbon cycle, developing of predictive models for climate change over decades to centuries, and basic research for biological sequestration of carbon. Basic research in Environmental Remediation continues, at a reduced level, supporting fundamental research at the interfaces of biology, chemistry, geology, hydrology, and physics for solutions to environmental contamination challenges and terminating high level waste research. The Medical Sciences research program continues its principal focus on the artificial retina and medical imaging, including radiopharmaceuticals for imaging, at FY 2006 levels. Support for user facilities increases to meet growing scientific and technical demands for users of the Environmental Molecular Sciences Laboratory (EMSL), Production Genomics Facility (PGF), Atmospheric Radiation Measurement (ARM) sites, and Free Air Carbon Dioxide Enrichment (FACE) sites.

HEP contributes to General Goal 5 by advancing understanding of the basic constituents of matter, dark energy and dark matter, the lack of symmetry between matter and antimatter in the current universe, and the possible existence of other dimensions, collectively revealing key secrets of the universe. The FY 2007 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 Fermilab and the B-factory at SLAC), to produce maximum scientific data. HEP and BES will jointly support accelerator operations at SLAC through the construction of the LCLS. The U.S. HEP program in FY 2007 will continue to lead the world with these forefront user facilities at Fermilab and SLAC, 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 (for example, neutrino physics) that will establish U.S. leadership in these areas (see Significant Shifts) in the next decade, when the centerpiece of the world HEP program will reside at CERN. The FY 2007 budget also provides support for final installation, commissioning, and initial operations of the U.S.-supplied components of the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN) Laboratory.

NP contributes to General Goal 5 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 which hold the nucleus together and determine the detailed structure and behavior of the atomic nuclei. The program builds and supports world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda. 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 reactors and national and homeland security. 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. A new Electron Beam Ion Source (EBIS) begins construction together with the National Aeronautics and Space Administration (NASA) to provide RHIC with more cost-effective, reliable operations. In addition to RHIC efforts, the High Energy Density Physics activities 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. At the FY 2007 level of funding, the accelerator provides beams simultaneously to all three experimental halls to better understand the structure of the nucleon. PED begins on a significant upgrade of the facility, the 12 GeV CEBAF Upgrade project. NP also continues efforts in nuclear structure/astrophysics, fundamental interactions, and neutrinos. Efforts at the Argonne Tandem Linear 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. Generic R&D in radioactive ion beam development, relevant for next-generation facilities in nuclear structure and astrophysics, is supported in FY 2007. The GRETINA gamma-ray tracking array, currently under fabrication, revolutionizes gamma ray detection technology and offers dramatically improved capabilities to study the structure of nuclei at ATLAS and HRIBF. The Fundamental Neutron Physics Beamline (FNPB) under fabrication at SNS will provide a world-class capability to study the neutron decay properties, leading to a refined characterization of the weak force. Investments are made to initiate the fabrication of a neutron Electric Dipole Moment experiment in the search for new physics beyond the Standard Model, for fabrication of instrumentation that will provide opportunities for U.S. involvement in the heavy-ion program at the CERN Large Hadron Collider, and for design and R&D associated with a Double Beta Decay experiment that will measure the absolute mass of the neutrino.

FES contributes to General Goal 5 by advancing the theoretical and experimental understanding of plasma and fusion science through our domestic activities and a close collaboration with international partners on specialized facilities abroad. FES also contributes to General Goal 5 through participation in ITER, an experiment to study and demonstrate the scientific and technical feasibility of fusion power. ITER is a multi-billion dollar international research project that will, if successful, advance progress towards developing fusion's potential as a commercially viable and clean source of energy near the middle of the century. The FY 2006 Appropriation provided for a slower start for the U.S. Contributions to the ITER project. The FY 2007 request provides for the continuation of the U.S. Contributions to the ITER MIE project. In FY 2007, the overall Total Project Cost remains unchanged from FY 2006, but the funding requested in FY 2007 is lower than shown in the profile in the FY 2006 budget, and slightly adjusted between the Total Estimated Cost (TEC) and Other Project Cost (OPC) categories to address domestic and international project priorities. 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, and installation.

Experimental research on tokamaks is continued in FY 2007, with increasing emphasis on physics issues of interest to the ITER project. Operations at the largest facility, the DIII-D tokamak at General Atomics (a private company), will increase from 7 weeks in FY 2006 to 12 weeks in FY 2007, while operations at C-Mod at MIT will increase from 14 to 15 weeks, and operations at the National Spherical Torus Experiment (NSTX) at PPPL will increase from 11 to 12 weeks. Fabrication of the National Compact Stellarator Experiment (NCSX) will continue along the new baseline established in July 2005 with completion expected in July 2009. The General Plasma Science program continues at approximately FY 2006 levels.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.22.00.00, Basic Energy Sciences	1,083,616	1,134,557	1,420,980
Program Goal 05.23.00.00, Advanced Scientific Computing Research	226,180	234,684	318,654
Program Goal 05.21.00.00, Biological and Environmental Research	566,597	579,831	510,263
Program Goal 05.19.00.00, High Energy Physics	722,906	716,694	775,099
Program Goal 05.20.00.00, Nuclear Physics	394,549	367,034	454,060
Program Goal 05.24.00.00, Fusion Energy Sciences	266,947	287,644	318,950
Subtotal, General Goal 5, World-Class Scientific Research Capacity	3,260,795	3,320,444	3,798,006
All Other			
Science Laboratories Infrastructure	37,498	41,684	50,888
Program Direction	154,031	159,118	170,877
Workforce Development for Teachers and Scientists	7,599	7,120	10,952
Safeguards and Security	72,773	73,630	76,592
Small Business Innovation Research/Small Business Technology Transfer	113,621	——	——
Total, All Other	385,622	281,552	309,309
Total, General Goal 5 (Science)	3,646,317	3,601,996	4,107,315

Major FY 2005 Accomplishments

An incident solar photon striking a semiconductor solar cell normally produces a single electron-hole pair (exciton) and some excess heat. Experimentalists have recently demonstrated that two or more excitons can be created by absorption of a single photon in an array of lead-selenide nanocrystals. This process is called “impact ionization” and is observed when the photon energy is greater than three times the band gap of the nanocrystal. Multiple excitons from a single photon are formed on the picosecond time scale, and the process occurs with up to 100% efficiency depending on the excess energy of the absorbed photon. If this process could be translated into an operational solar cell, the gain in efficiency for converting light to electrical current would be greater than 35%.

Diatoms are simple single-celled algae, covered with elegant and often very beautiful casings sculpted from silica. They share biochemical features of both plants and animals and are related to the organisms that make up the well known White Cliffs of Dover in England. Scientists have taken a big step toward resolving the paradoxical nature of these odd microbes by sequencing the genome of the marine diatom *Thalassiosira pseudonana*. Analyses of these genes and the proteins they encode confirm that diatoms, in their evolutionary history, apparently acquired new genes by engulfing microbial neighbors including, possibly, genes that provided the diatom with all the machinery necessary for photosynthesis. Diatoms occupy vast swaths of ocean and fresh water, where they play a key role in the global carbon cycle. Diatom photosynthesis yields 19 billion tons of organic carbon—about 40% of the marine carbon produced each year—and thus represent one of nature's key defenses against global warming. Progress in analyzing the diatom genome is also shedding light on how a diatom constructs its intricately patterned glass shell, progress that could benefit both materials and climate change scientists.

The universe may have begun as a "perfect" liquid, not a gas. In April 2005, nuclear physicists working on the four experiments at RHIC presented "White Papers" documenting details and summarizing the evidence for an extraordinary new state of matter obtained from the first three years of RHIC operations. These latest results show that a new state of hot, dense matter was created out of quarks and gluons, but quite different and even more remarkable than had been previously predicted. The matter created in heavy-ion collisions appears to behave like a near "perfect" liquid rather than a fiery gas of free quarks and gluons. The word "perfect" refers to the liquid's viscosity—a friction like property that impedes a fluid's ability to flow. A perfect liquid has no viscosity. The RHIC results are consistent with "ideal" hydrodynamic calculations suggesting that the lowest viscosity possible in a "Quark-Gluon Plasma (QGP) fluid" may be achieved— a stunning discovery that could revise physicists' conception of the earliest moments of the universe.

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.

The current focus is to establish outcome- and output-oriented goals, the successful completion of which will lead to benefits to the public, such as increased national security and energy security, and improved environmental conditions. DOE has incorporated feedback from OMB into the FY 2006 Budget Request, and the Department will take the necessary steps to continue to improve performance.

SC did not complete PARTs for the FY 2007 Budget. 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." The full PARTs are available on the OMB website at http://www.whitehouse.gov/omb/budget/fy2005/part.html. SC expects to stagger updated PART reviews in the future.

SC has taken steps to enhance public understanding of our revised performance measures. The PART website (http://www.science.doe.gov/measures/) has been improved to better explain what each scientific measure means, why it is important to the Department and/or the research community, and how progress will be measured. Roadmaps with more detailed information on tracking progress toward the long-term measures have been developed with the Scientific Advisory Committees and are posted to this PART website. The Advisory Committees will review progress toward those measures vis-à-vis the roadmaps every three to five years. The first reviews will be conducted in FY 2006. The results of these reviews will be published on the PART website as they become available.

For the FY 2007 budget, OMB has developed PARTWeb—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the new http://ExpectMore.gov website and will improve public access to PART assessments and follow up actions. New actions for Science in 2006 include:

- Implementing the recommendations of past and new external assessment panels, as appropriate;
- Engaging the Advanced Scientific Computing Advisory Committee and other outside groups in regular, thorough scientific assessments of the quality, relevance, and performance of its research portfolio and computing/network facilities;
- A detailed corporate solution for managing and operating the High Flux Isotope Reactor;
- Engaging the National Academies in an independent assessment of the scientific basis and business case for microbial genomics research efforts;
- Developing strategic and implementation plans in response to multiple Congressional requirements for ITER and Fusion Energy Sciences;
- Re-engaging the Fusion Energy Sciences Advisory Committee in a study of the how the program could best evolve over the coming decade to take into account new and upgraded international facilities;
- Developing a strategy and implementation plan for particle accelerator research and development, including a potential international linear collider;
- Engaging the National Academies to help develop a realistic long term plan for High Energy Physics that is based on prioritized scientific opportunities and input from across the scientific community;
- Engaging the National Academies, including experts outside of nuclear physics, to study the scientific capabilities of a proposed rare isotope accelerator in an international context; and
- Maximizing operational efficiency of major Nuclear Physics experimental facilities in response to increasing power costs.

Significant Policy or Program Shifts

Basic Energy Sciences—Over the next two to three years, the Spallation Neutron Source (SNS) will fabricate and commission instruments and increase power to full levels. A new major item of equipment is funded that will allow the fabrication of four to five additional instruments for the SNS, thus nearly completing the initial suite of twenty four instruments that can be accommodated in the high-power target station. BES also supports energy security through basic research for effective solar energy utilization, basic research for the hydrogen economy, and basic research underpinning advanced nuclear energy power.

Advanced Scientific Computing Research— In FY 2007, ASCR supports increases in SciDAC activities, the initiation of new university based competition for SciDAC Institutes, and enhancements to SciDAC that develop leadership class computing simulations for petaflop-scale computers. Increases in funding for both production and leadership computing facilities will enable continued scientific leadership through high performance computing. The success of this effort is built on the enhancements to the research and evaluation prototype and computer science research activities. The Research and Evaluation Prototypes activity will prepare users for the next generations of scientific computers and reduce the risk of major procurements. Increases in funding would also enable ESnet to evolve to manage the increased data flows from petascale computers and the experimental facilities that are critical to the Nation's future.

Biological and Environmental Research—Development of a global biotechnology-based energy infrastructure requires a science base that enables scientists to redesign specific proteins, biochemical pathways, and even entire plants or microbes. Studies have suggested that, by 2100, biotechnology-based energy use could equal all global fossil energy use today. Two examples of biofuels are ethanol derived from the cellulose in plant cell walls (cellulosic ethanol) and hydrogen produced from water using energy from the sun (biophotolytic hydrogen). Within the Genomics: GTL program, BER will develop the understanding needed to advance biotechnology-based strategies for biofuel production. In addition, the FY 2007 budget includes funds for the continued expansion of the Genomics: GTL program—a program at the forefront of the biological revolution. Funding reductions are initiated in the Environmental Remediation Research and in the Climate Change Research Subprograms. High level waste, ocean sciences, and ocean carbon sequestration research are terminated within these two subprograms.

High Energy Physics—Our highest priority HEP R&D effort is the development of an International Linear Collider (ILC), and this request significantly advances the ILC R&D program. Pre-conceptual R&D for the ILC is doubled to enable a strong U.S. leadership role as a part of a comprehensive, coordinated international R&D program. In addition, R&D for other accelerator and detector technologies will continue at an increased level relative to FY 2006. Project engineering and design (PED) will begin on a new detector optimized to detect electron neutrinos, the Electron Neutrino Appearance (EνA) Detector, which will utilize the existing NuMI beam. Participation will begin in a reactor-based neutrino experiment, and R&D for a high-intensity neutrino super beam facility and a double beta decay experiment will continue. These efforts are part of a coordinated neutrino program developed from an American Physical Society study and a joint High Energy Physics Advisory Panel/Nuclear Science Advisory Committee review. In order to explore the nature of dark energy, conceptual R&D for the Super Nova/Acceleration Probe (SNAP) mission concept will continue in FY 2007. SNAP is expected to be a mission concept proposed for a potential interagency-sponsored experiment with NASA, the Joint Dark Energy Mission (JDEM). In addition, to fully determine the nature of dark energy, independent and complementary measurements are scientifically advisable. In FY 2007, additional R&D will be done for ground facilities and/or space-based facilities which could provide these measurements.

Nuclear Physics—The FY 2007 budget request increases support for operations and research by approximately 21% compared to FY 2006. At this level, operations of the four NP National User Facilities allow researchers to make effective progress towards the program's scientific goals and milestones. This budget request supports initiation of research efforts in the CERN LHC heavy ion program and starts PED activities for the 12 GeV CEBAF Upgrade project. NP also supports increases for research relevant to advanced nuclear fuel cycles. While we have a relatively good understanding of the origin of the chemical elements in the cosmos lighter than iron, the production of the elements from iron to uranium remains a puzzle. A next-generation exotic beam facility would allow the U.S. to play a leading role in nuclear structure and astrophysics studies in the next decade. Modest funding for generic R&D in exotic beam development is supported in FY 2007.

Fusion Energy Sciences—The FY 2007 budget continues the redirection of the fusion program to prepare for and participate in the international ITER project. The redirection will require modest reductions in several program elements not directly related to ITER. The FY 2007 request for the U.S. Contributions to ITER MIE project reflects a more modest first two years than was contained in the FY 2006 President's Budget, but maintains the overall Total Project Cost funding cap of $1,122,000,000. The reductions allow for the U.S. to be more consistent with the other ITER parties in the pace of starting the long lead procurements, in providing increased numbers of personnel to the ITER Organization, and in providing cash for common expenses. The profile is preliminary until the baseline scope, cost, and schedule for the MIE project are established, and the Director General Nominee and ITER Organization have achieved a standard mode of operation. SciDAC efforts will increase and will continue development of collaboratory tools to facilitate international fusion collaborations and initiate development of an integrated software environment that can accommodate the wide range of space and time scales and the multiple physical phenomena that are encountered in simulations of fusion systems. The Fusion Simulation Project is a major initiative involving plasma physicists, applied mathematicians, and computer scientists to create a comprehensive set of models of fusion systems, combined with the algorithms required to implement the models and the computational infrastructure to enable them to work together. High Energy Density Physics, Plasma Technology and Materials Research, Experimental Plasma Research, and Fusion Theory will be reduced.

Scientific Laboratory Infrastructure—In FY 2007, SLI will initiate funding for four construction projects: the Seismic Safety Upgrade of Buildings, Phase I, at the Lawrence Berkeley National Laboratory; the Modernization of Building 4500N, Wing 4, Phase I, at the Oak Ridge National Laboratory; the Building Electrical Services Upgrade, Phase II, at the Argonne National Laboratory; and Renovate Science Lab, Phase I, at the Brookhaven National Laboratory. Funding for the Pacific Northwest National Laboratory Physical Sciences Facility is requested in the National Nuclear Security Administration's (NNSA's) Nuclear Non-Proliferation R&D program for FY 2007. This project is co-funded by SC, NNSA, and the Department of Homeland Security. The SLI program will continue full funding for demolition of the Bevatron at Lawrence Berkeley National Laboratory. General plant project (GPP) funding is terminated in FY 2007 because it is supported in other SC programs' budgets in FY 2007.

Science Program Direction—Program direction funding increases by 7.4%, with most of the increase to support an additional 25 FTEs planned to be hired in support of the overall Science program, which is increased by 14.1% in the FY 2007 request. The increase also supports a 2.2% pay raise; an increased cap for SES basic pay; other pay related costs such as the government's contributions for employee health insurance and Federal Employees' Retirement System (FERS); escalation of non-pay categories, such as travel, training, and contracts; and increased e-Gov assessments and other fixed operating requirements across the SC complex. Finally, the increase will cover requirements not requested in previous SCPD budget requests, including travel expenses of SC Advisory Committee members and requirements related to Appendix A of OMB Circular A-123, Management's Responsibility for Internal Control.

Workforce Development for Teachers and Scientists—The Laboratory Science Teacher Professional Development (LSTPD) program increases to expand participation from 108 teachers in FY 2006 to 300 in FY 2007. The Faculty Sabbatical activity was initiated in FY 2005 for faculty from Minority Serving Institutions (MSI) and reduced in FY 2006 due to feedback from MSI faculty who expressed their inability to participate in sabbatical programs and a preference for shorter fellowship-type opportunities. FY 2007 participation will be reduced to two faculty members. The Science Undergraduate Laboratory Internship (SULI) programs will be increased to add approximately 55 students. The Albert Einstein Distinguished Educator Fellowship and the National and Middle School Science Bowls will all continue.

Safeguards and Security—The FY 2007 budget will ensure adequate security posture for SC facilities by protecting fundamental science, national security, and the health and safety of DOE and contractor employees, the public and the environment. FY 2007 funding will cover the implementation of the 2003 Design Basis Threat (DBT). In FY 2007, an increase in funding for the Cyber Security program element is being requested to begin to address the promulgation of new National Institute of Standards and Technology (NIST) requirements which are statutorily required by the Federal Information Security Management Act (FISMA) to improve the Federal and SC laboratory cyber security posture.

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:

- Quadrangle Common Area design and construction at Oak Ridge National Laboratory. This FY 2004 and FY 2005 effort includes lawn, landscaping, sidewalks, lighting, and street improvements to an area of approximately 71,000 square feet. TEC: $2,697,000.
- East Campus Storm Water Upgrades at Oak Ridge National Laboratory. This FY 2005 project will upgrade the East Campus storm water drainage system to prevent flooding of new East Campus facilities. Recent storm modeling of the East Campus watershed has determined that a 500-year storm could produce substantial flooding in the Oak Ridge East Campus. TEC: $750,000
- 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.

The following displays IGPP funding by site:

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Oak Ridge National Laboratory	9,000	10,000	8,000
Pacific Northwest National Laboratory	2,000	2,000	5,000
Argonne National Laboratory	—	—	2,000
Total, IGPP	11,000	12,000	15,000

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 2005	FY 2006	FY 2007
Ames Laboratory	1,023	915	858
Argonne National Laboratory	26,413	26,327	28,332
Brookhaven National Laboratory	21,511	22,925	23,098
Fermi National Accelerator Laboratory	6,033	8,893	6,738
Lawrence Berkeley National Laboratory	11,175	13,000	15,440
Lawrence Livermore National Laboratory	2,735	2,767	2,822
Massachusetts Institute of Technology	569	—	—
Oak Ridge Institute for Science and Education	546	475	380
Oak Ridge National Laboratory	23,372	23,080	23,075
Oak Ridge National Laboratory facilities at Y-12	738	500	500
Pacific Northwest National Laboratory	1,868	1,895	1,476
Princeton Physics Plasma Laboratory	4,387	5,045	5,300
Sandia National Laboratory	1,905	1,960	1,999
Stanford Linear Accelerator Center	5,837	5,278	5,140
Thomas Jefferson National Accelerator Facility	2,676	3,440	2,518
Total, Indirect-Funded Maintenance and Repair	110,788	116,500	117,676

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 2005	FY 2006	FY 2007
Brookhaven National Laboratory	2,290	2,974	2,974
Fermilab National Accelerator Facility	3,028	3,628	3,628
Notre Dame Radiation Laboratory	172	145	150
Oak Ridge National Laboratory	15,842	13,748	13,929
Oak Ridge National Laboratory facilities at Y-12	79	—	—
Oak Ridge Office	1,771	1,891	2,019
Stanford Linear Accelerator Center	1,079	2,520	3,480
Thomas Jefferson National Accelerator Facility	44	50	52
Total, Direct-Funded Maintenance and Repair	24,305	24,956	26,232

Deferred Maintenance Backlog Reduction

SC is planning an increased focus on reducing the backlog of deferred maintenance activities. SC will set targets for each of its laboratories for activities specifically focused on reduction of the backlog of these activities. The current deferred maintenance backlog at SC laboratories is estimated to be $660,000,000 and this amount will be our deferred maintenance baseline from which we will measure improvement. Deferred maintenance activities are primarily funded by the laboratories as overhead, charged to all uses of the laboratory facilities. The overall target for deferred maintenance at SC laboratories will be $19,800,000 in FY 2007. 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 2005	FY 2006	FY 2007
Argonne National Laboratory	—	—	2,574
Brookhaven National Laboratory	—	—	5,940
Fermi National Accelerator Laboratory	—	—	1,980
Lawrence Berkeley National Laboratory	—	—	2,178
Oak Ridge National Laboratory	—	—	5,544
Princeton Physics Plasma Laboratory	—	—	396
Stanford Linear Accelerator Center	—	—	792
Thomas Jefferson National Accelerator Facility	—	—	396
Total, Deferred Maintenance Backlog Reduction	—	—	19,800

Selected Administration Priorities

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Hydrogen Fuel Initiative	29,183	32,500	50,000
Climate Change Science Program	126,985	130,646	126,187
Networking and Information Technology Research and Development	246,846	255,830	344,672
National Nanotechnology Initiative	207,837	206,404	256,914
ITER (TPC)	——	19,315	60,000

Science
Office of Science
Funding by Site by Program

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Ames Laboratory			
Basic Energy Sciences	23,538	20,410	20,857
Advanced Scientific Computing Research	1,681	1,450	562
Biological and Environmental Research	800	——	——
Science Laboratories Infrastructure	210	150	——
Workforce Development for Teachers and Scientists	65	65	227
Safeguards and Security	505	507	570
Total, Ames Laboratory	26,799	22,582	22,216
Ames Site Office			
Science Program Direction	470	453	520
Argonne National Laboratory			
Basic Energy Sciences	180,613	171,629	190,810
Advanced Scientific Computing Research	13,145	9,918	28,174
Biological and Environmental Research	26,291	27,297	27,713
High Energy Physics	10,829	8,939	9,748
Nuclear Physics	23,158	18,762	23,682
Fusion Energy Sciences	971	990	960
Science Laboratories Infrastructure	2,457	1,246	3,697
Workforce Development for Teachers and Scientists	1,833	298	2,056
Safeguards and Security	8,671	8,570	8,462
Total, Argonne National Laboratory	267,968	247,649	295,302
Argonne Site Office			
Science Program Direction	3,413	3,677	3,813
Berkeley Site Office			
Science Program Direction	3,361	3,675	4,241

	FY 2005	FY 2006	FY 2007
	(dollars in thousands)		
Brookhaven National Laboratory			
Basic Energy Sciences	89,876	101,633	133,783
Advanced Scientific Computing Research	1,000	673	——
Biological and Environmental Research	23,620	20,172	18,074
High Energy Physics	30,648	26,542	30,193
Nuclear Physics	158,441	146,832	183,255
Science Laboratories Infrastructure	7,706	4,996	5,100
Workforce Development for Teachers and Scientists	734	436	1,013
Safeguards and Security	11,335	11,229	10,967
Total, Brookhaven National Laboratory	323,360	312,513	382,385
Brookhaven Site Office			
Science Program Direction	3,267	3,537	3,643
Chicago Office			
Basic Energy Sciences	180,295	130,276	130,351
Advanced Scientific Computing Research	41,556	24,853	18,164
Biological and Environmental Research	220,252	109,654	75,868
High Energy Physics	127,944	117,772	120,152
Nuclear Physics	73,339	59,258	61,664
Fusion Energy Sciences	135,356	134,241	129,817
Science Laboratories Infrastructure	1,848	——	1,520
Science Program Direction	25,306	24,719	26,162
Workforce Development for Teachers and Scientists	36	——	——
Safeguards and Security	185	825	3,400
SBIR/STTR	113,621	——	——
Total, Chicago Office	919,738	601,598	567,098
Fermi National Accelerator Laboratory			
Advanced Scientific Computing Research	646	1,215	——
High Energy Physics	318,316	298,533	320,367
Nuclear Physics	33	——	——
Fusion Energy Sciences	——	3	——
Science Laboratories Infrastructure	662	491	——
Workforce Development for Teachers and Scientists	62	50	308
Safeguards and Security	3,015	2,893	3,221
Total, Fermi National Accelerator Laboratory	322,734	303,185	323,896

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Fermi Site Office			
Science Program Direction	2,185	2,235	2,346
Golden Field Office			
Basic Energy Sciences	——	4	4
Advanced Scientific Computing Research	——	3	——
Biological and Environmental Research	——	3	——
High Energy Physics	——	4	——
Nuclear Physics	——	3	——
Workforce Development for Teachers and Scientists	622	250	835
Total, Golden Field Office	622	267	839
Idaho National Laboratory			
Basic Energy Sciences	353	225	225
Biological and Environmental Research	3,670	1,566	1,190
Fusion Energy Sciences	2,499	2,380	2,334
Workforce Development for Teachers and Scientists	75	70	340
Total, Idaho National Laboratory	6,597	4,241	4,089
Idaho Operations Office			
Biological and Environmental Research	1,113	——	——
Lawrence Berkeley National Laboratory			
Basic Energy Sciences	135,564	110,437	125,497
Advanced Scientific Computing Research	71,546	65,408	77,559
Biological and Environmental Research	71,818	71,517	72,671
High Energy Physics	43,101	40,834	44,812
Nuclear Physics	18,784	18,399	20,706
Fusion Energy Sciences	6,048	5,653	4,911
Science Laboratories Infrastructure	8,199	15,009	21,500
Workforce Development for Teachers and Scientists	799	379	885
Safeguards and Security	5,733	4,723	4,981
Total, Lawrence Berkeley National Laboratory	361,592	332,359	373,522

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Lawrence Livermore National Laboratory			
Basic Energy Sciences	3,405	2,819	2,854
Advanced Scientific Computing Research	6,734	4,743	1,800
Biological and Environmental Research	26,149	24,224	25,209
High Energy Physics	2,140	1,951	2,196
Nuclear Physics	1,084	643	905
Fusion Energy Sciences	13,751	13,282	12,025
Science Laboratories Infrastructure	150	150	——
Workforce Development for Teachers and Scientists	50	——	78
Total, Lawrence Livermore National Laboratory	53,463	47,812	45,067
Los Alamos National Laboratory			
Basic Energy Sciences	27,624	22,753	21,993
Advanced Scientific Computing Research	3,879	2,832	2,075
Biological and Environmental Research	20,825	17,675	15,479
High Energy Physics	809	540	590
Nuclear Physics	9,647	8,008	10,515
Fusion Energy Sciences	3,831	3,946	3,356
Workforce Development for Teachers and Scientists	50	50	361
Total, Los Alamos National Laboratory	66,665	55,804	54,369
National Energy Technology Laboratory			
Basic Energy Sciences	82	100	——
Biological and Environmental Research	31	——	——
High Energy Physics	81	——	——
Nuclear Physics	16	100	——
Fusion Energy Sciences	81	3	——
Science Laboratories Infrastructure	——	275	——
Workforce Development for Teachers and Scientists	127	263	500
Total, National Energy Technology Laboratory	418	741	500
National Renewable Energy Laboratory			
Basic Energy Sciences	8,043	7,197	7,403
Advanced Scientific Computing Research	150	150	150
Biological and Environmental Research	400	569	875
Workforce Development for Teachers and Scientists	52	——	——
Total, National Renewable Energy Laboratory	8,645	7,916	8,428
NNSA Service Center/Albuquerque			
Biological and Environmental Research	850	800	——

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Oak Ridge Institute for Science and Education			
Basic Energy Sciences	3,455	810	810
Advanced Scientific Computing Research	315	600	——
Biological and Environmental Research	5,557	4,088	4,159
High Energy Physics	278	50	——
Nuclear Physics	1,067	590	703
Fusion Energy Sciences	1,186	1,215	788
Science Laboratories Infrastructure	565	768	——
Science Program Direction	39	——	——
Workforce Development for Teachers and Scientists	1,470	853	1,545
Safeguards and Security	1,403	1,359	1,489
Total, Oak Ridge Institute for Science and Education	15,335	10,333	9,494
Oak Ridge National Laboratory			
Basic Energy Sciences	263,802	276,351	322,480
Advanced Scientific Computing Research	68,786	61,098	82,822
Biological and Environmental Research	45,408	39,746	36,266
High Energy Physics	836	180	182
Nuclear Physics	20,941	19,668	23,349
Fusion Energy Sciences	22,340	20,560	18,650
Science Laboratories Infrastructure	2,188	1,283	8,047
Safeguards and Security	11,891	9,461	8,396
Total, Oak Ridge National Laboratory	436,192	428,347	500,192
Oak Ridge Office			
Basic Energy Sciences	106	80	80
Advanced Scientific Computing Research	200	80	——
Biological and Environmental Research	694	677	373
High Energy Physics	108	16	80
Nuclear Physics	106	80	——
Fusion Energy Sciences	106	80	——
Science Laboratories Infrastructure	5,039	5,028	5,079
Science Program Direction	42,422	42,534	44,252
Workforce Development for Teachers and Scientists	90	90	90
Safeguards and Security	12,862	16,107	17,975
Total, Oak Ridge Office	61,733	64,772	67,929

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Pacific Northwest National Laboratory			
Basic Energy Sciences	15,149	14,763	15,182
Advanced Scientific Computing Research	3,408	6,690	350
Biological and Environmental Research	86,647	80,203	85,695
Fusion Energy Sciences	1,330	1,285	815
Science Laboratories Infrastructure	4,960	4,950	—
Workforce Development for Teachers and Scientists	917	514	1,035
Safeguards and Security	11,133	10,044	10,993
Total, Pacific Northwest National Laboratory	123,544	118,449	114,070
Pacific Northwest Site Office			
Science Program Direction	5,277	5,438	5,553
Princeton Plasma Physics Laboratory			
Advanced Scientific Computing Research	573	1,143	—
High Energy Physics	225	225	249
Fusion Energy Sciences	74,999	90,953	129,956
Science Laboratories Infrastructure	239	119	—
Workforce Development for Teachers and Scientists	135	115	392
Safeguards and Security	1,938	1,819	1,953
Total, Princeton Plasma Physics Laboratory	78,109	94,374	132,550
Princeton Site Office			
Science Program Direction	1,554	1,618	1,668
Sandia National Laboratories			
Basic Energy Sciences	54,225	38,808	43,822
Advanced Scientific Computing Research	10,693	4,122	2,595
Biological and Environmental Research	7,125	4,631	4,213
Fusion Energy Sciences	3,454	2,022	1,655
Workforce Development for Teachers and Scientists	—	—	258
Total, Sandia National Laboratories	75,497	49,583	52,543
Savannah River National Laboratory			
Basic Energy Sciences	200	200	200
Biological and Environmental Research	873	804	691
Fusion Energy Sciences	37	10	—
Workforce Development for Teachers and Scientists	—	—	258
Total, Savannah River National Laboratory	1,110	1,014	1,149

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Savannah River Operations Office			
Biological and Environmental Research	7,748	1,000	——
Stanford Linear Accelerator Center			
Basic Energy Sciences	95,232	150,763	215,469
Advanced Scientific Computing Research	485	57	——
Biological and Environmental Research	4,150	4,350	4,311
High Energy Physics	169,036	144,574	145,964
Science Laboratories Infrastructure	3,275	5,539	5,770
Workforce Development for Teachers and Scientists	150	135	150
Safeguards and Security	2,335	2,377	2,437
Total, Stanford Linear Accelerator Center	274,663	307,795	374,101
Stanford Site Office			
Science Program Direction	1,647	1,670	2,134
Thomas Jefferson National Accelerator Facility			
Advanced Scientific Computing Research	50	——	——
Biological and Environmental Research	810	400	400
High Energy Physics	50	480	927
Nuclear Physics	86,815	78,127	96,371
Science Laboratories Infrastructure	——	175	——
Workforce Development for Teachers and Scientists	332	95	502
Safeguards and Security	1,468	1,231	1,311
Total, Thomas Jefferson National Accelerator Facility	89,525	80,508	99,511
Thomas Jefferson Site Office			
Science Program Direction	1,407	1,457	1,500

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Washington Headquarters			
Basic Energy Sciences	2,054	85,299	189,160
Advanced Scientific Computing Research	1,333	49,649	104,403
Biological and Environmental Research	11,766	170,455	137,076
High Energy Physics	18,505	76,054	99,639
Nuclear Physics	1,118	16,564	32,910
Fusion Energy Sciences	958	11,021	13,683
Science Laboratories Infrastructure	—	1,505	175
Science Program Direction	63,683	68,105	75,045
Workforce Development for Teachers and Scientists	—	3,457	119
Safeguards and Security	299	2,485	437
Total, Washington Headquarters	99,716	484,594	652,647
Total, Science	3,646,317	3,601,996	4,107,315

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 2007.

Advanced Scientific Computing Research

- The Leadership Computing activity will be initiated to provide up to 100 teraflops of high-performance computing capability with low electrical power consumption to enable scientific advances.

Science Laboratories Infrastructure

- The Argonne National Laboratory (ANL) Building Electrical Services Upgrade, Phase II project is initiated to upgrade critical portions of the electrical power distribution system in twelve research buildings and support facilities, including the Canal Water Plant supplying cooling water for site experiments.

Lawrence Berkeley National Laboratory

Basic Energy Sciences

- The Molecular Foundry, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2007.
- Advanced Light Source (ALS) User Support Building (USB) will begin design in FY 2007. The USB will provide user support space to accommodate the growth in the number of users and future expansion of the ALS.

Advanced Scientific Computing Research

- Funding for the National Energy Research Scientific Computing Center (NERSC) and the Energy Science Network (ESnet) is increased from FY 2006. This will enable significant increases in the high performance production computing capacity and network capacity to meet SC's needs.

Science Laboratories Infrastructure

- The Seismic Safety Upgrade of Buildings, Phase I project is initiated to address the seismic upgrade of laboratory buildings where high life-safety risks have been identified.
- Demolition of the Bevatron is fully funded to free-up about 7.5% of the total building space for future missions.

Brookhaven National Laboratory

Basic Energy Sciences

- The **Center for Functional Nanomaterials**, one of five DOE Nanoscale Science Research Centers, is in its final year of construction in FY 2007.
- Support is provided for Project Engineering Design and Other Project Costs for the **National Synchrotron Light Source-II** (NSLS-II), which will be built as a replacement for NSLS-I, 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 will provide the world's finest capabilities for x-ray imaging.

Science Laboratories Infrastructure

- The Renovate Science Laboratory, Phase I project is initiated to upgrade and rehabilitate existing obsolete and unsuitable laboratory facilities into modern, efficient facilities compatible with world-class scientific research.

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 2007.

Oak Ridge National Laboratory

Basic Energy Sciences

- Construction of the **Spallation Neutron Source** (SNS) will be completed during the 3rd quarter of FY 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 is funded in FY 2007 that 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. Support also is provided for research and development (R&D) for a power upgrade to the SNS.
- The **Center for Nanophase Materials Sciences**, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2007.

Advanced Scientific Computing Research

- The Leadership Computing Facility (LCF) at the Oak Ridge National Laboratory (ORNL) will be enhanced to deliver 250 teraflops of peak capability in FY 2007 for scientific applications.

Fusion Energy Sciences

- ORNL, in partnership with Princeton Plasma Physics Laboratory (PPPL), shares the responsibility for managing the U.S. contributions to the ITER project by further engaging the U.S. fusion community and industry to provide the U.S. hardware contributions and the U.S. secondees to be assigned to the ITER Organization abroad. There will be significant international cooperation between the U.S. ITER Project Office (a partnership between PPPL and ORNL), the international ITER Organization, and the other ITER parties.

Science Laboratories Infrastructure

- The Modernization of Building 4500N, Wing 4, Phase I, project is initiated to rehabilitate a facility housing many of the laboratory's chemical laboratory facilities, as well as administrative offices and the medical clinic.

Princeton Plasma Physics Laboratory

Fusion Energy Sciences

- PPPL, in partnership with ORNL, will continue to manage the U.S. contributions to the ITER project by further engaging the U.S. fusion community and industry to provide the U.S. hardware contributions and the U.S. secondees to be assigned to the ITER Organization abroad. There will be significant international cooperation and coordination between the U.S. ITER Project Office (a partnership between PPPL and ORNL), the international ITER Organization, and the other ITER parties.

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 2007.

Fusion Energy Sciences

- Research in plasma-facing components and plasma materials interactions for the base program will be reduced; however, Sandia is expected to play a major role in the first wall and shield area of the ITER project.

Stanford Linear Accelerator Center

Basic Energy Sciences

- The **Linac Coherent Light Source (LCLS)** will continue Project Engineering Design and construction. Funding is provided separately for preconceptual design and fabrication of instruments for the facility. Funding is also provided to partially support operation of the SLAC linac. This marks the second year of the transition to LCLS operations at SLAC.

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 37 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 SciDAC teams. Ames also participates in Integrated Software Infrastructure Center (ISIC) activities that focus on specific software challenges confronting users of terascale computers.

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

Introduction

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 Office of Science (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 1,508 acres in suburban Chicago. The laboratory consists of 99 buildings (4.5 million gross square feet of space) with an average building age of 34 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 participates on a number of the SciDAC teams. Further, it participates in ISIC activities that focus on specific software challenges confronting users of terascale computers. As part of the Leadership Computing Facility (LCF) activity, ANL will acquire up to 100 teraflops of high-performance computing with low electrical power consumption to advance science and will continue to focus on testing and evaluating leading edge computers.

Biological and Environmental Research

ANL operates a high-throughput national user facility for protein crystallography at APS that also supports a growing environmental science community. In support of climate change research, it coordinates the operation and development of the Southern Great Plains, Tropical Western Pacific, and North Slope of Alaska Atmospheric Radiation Measurement (ARM) sites. ANL also conducts research on aerosol processes and properties and to develop and apply software to enable efficient long-term climate simulations on distributed-memory multiprocessor computing platforms. Research is conducted to understand the molecular control of genes and gene pathways in microbes. In conjunction with the ORNL and the Pacific Northwest National Laboratory (PNNL) and six universities, ANL is a participating lab in the Carbon Sequestration in Terrestrial Ecosystems (CSiTE) consortium, focusing on research to understand the processes controlling the rate of soil carbon accretion. APS supports environmental remediation sciences researchers and ANL conducts environmental remediation sciences research.

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 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, such as the proposed Rare Isotope Accelerator (RIA) facility; 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** 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% of the beams are exotic (radioactive) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus, the 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 exotic beam facilities. The combination of versatile beams and powerful instruments enables ~200 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

Introduction

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

Introduction

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 is a multiprogram laboratory located on 5,300 acres in Upton, New York. The laboratory consists of 345 SC buildings (3.9 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 teams. It also participates in ISIC activities that focus on specific software challenges confronting users of terascale 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. BNL conducts research into new instrumentation for detecting x-rays and neutrons. Research is also conducted on the molecular mechanisms of cell responses to low doses of radiation. 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 atmospheric field campaigns and aerosol research to the program. The ASP chief scientist is at BNL. BNL scientists play a leadership role in the operation of the Free-Air Carbon Dioxide Enrichment (FACE) facility at the Duke Forest used 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 State University of New York-Stony Brook and has instituted a new internal initiative EnviroSuite to support a growing community of environmental users at NSLS.

High Energy Physics

The HEP program supports physics research and technology 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; a smaller R&D activity directed towards the ATLAS detector within the heavy-ion program at the LHC at CERN; 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 1,000 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 have been 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 or are expected to complete their research programs and focus on data analysis in the near future. 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 (NNDC)** is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States' repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The NNDC is a resource 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

Introduction

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 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. Chicago 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 Chicago is shared SC-wide through the Integrated Support Center concept. Chicago 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 located in 24 states supporting approximately 126 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 185 research grants at 90 colleges/universities located in 35 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 Tandem Van de Graaff and Center for Experimental Nuclear and Particle Astrophysics (CENPA); and the newly established Research and Engineering Center at the Massachusetts Institute for Technology. These accelerator facilities offer niche capabilities and opportunities not available at the national user facilities, or many foreign low-energy laboratories, such as specialized sources and targets, opportunities for extended experiments, and specialized instrumentation. Also supported is the Institute for Nuclear Theory (INT) at the University of Washington, a premier international center for new initiatives and collaborations in nuclear theory research.

Fusion Energy Sciences

The Fusion Energy Sciences (FES) program funds research at more than 50 colleges and universities located in approximately 30 states. FES also funds 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 358 buildings (2.3 million gross square feet of space) with an average building age of 39 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 2,500 scientific users, scientists from universities and laboratories throughout the U.S. and around the world, use Fermilab for their research. Fermilab's mission is the goal of high-energy physics: to 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 teams.

High Energy Physics

Fermilab operates the **Tevatron** accelerator and colliding beam facility, which consists of a four-mile ring of superconducting magnets and two large multi-purpose detectors, and is capable of accelerating protons and antiprotons to an energy of one trillion electron volts (1 TeV). The Tevatron is the highest energy proton accelerator in the world, and will remain so until the LHC begins commissioning at CERN in 2007. With the shutdown of the Large Electron-Positron (LEP) collider at CERN in 2000, the Tevatron became the only operating particle accelerator at the energy frontier. The Tevatron complex also includes the Booster and the Main Injector, pre-accelerators to the Tevatron. The Main Injector, which is used for the pre-acceleration of protons and production of antiprotons as a part of the Tevatron complex, is also used independently of the Tevatron for a 120 GeV fixed target program, including the **Neutrinos at the Main Injector (NuMI)** beamline which started operation in 2005. Fermilab is the principal experimental facility for HEP. 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. Limited funding increases would be applied to security systems and the Foreign Visits and Assignments program.

Fermi Site Office

Introduction

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.

Biological and Environmental Research

INL is conducting research in subsurface science relating to clean up of the nuclear weapons complex with an emphasis on subsurface science.

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 106 buildings (1.6 million gross square feet of space) with an average building age of 36 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 design in FY 2007.

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 the mathematics and computer science, as well as research in advanced computing software tools. It participates in several scientific application partnerships, including the partnership with the BES program in nanoscale science, and participates on a number of the SciDAC teams. 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 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. LBNL participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

LBNL is one of the major national laboratory partners forming the Joint Genome Institute (JGI) whose principal goals are high-throughput DNA sequencing techniques and studies on the biological functions associated with the newly sequenced human DNA. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation, on the use of model organisms to understand and characterize the human genome, and on microbial systems biology research as part of Genomics:GTL. 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 is also used by a growing environmental science community. LBNL also supports the environmental remediation sciences research and the geophysical and biophysical and biochemical research capabilities for field sites in that program.

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.

LBNL conducts research into new technologies for the detailed characterization of complex environmental contamination. 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

The Low Energy subprogram has supported operations and the research program of the 88-Inch Cyclotron, whose operations transitioned in FY 2004 from a national user facility to a dedicated in-house facility with partial operational support from other federal agencies to carry out their programs. Other activities 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; R&D and conceptual design activities directed towards a detector upgrade for the ALICE detector heavy-ion program at the Large Hadron Collider (LHC) at Organisation Europèanne 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.

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 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 and SciDAC efforts. It also participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

LLNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. 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, and on the use of model organisms to understand and characterize the human genome.

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, 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 the mathematics and computer science and in advanced computing software tools. It also participates in several scientific application partnerships and participates on a number of the SciDAC teams. LANL participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

LANL is one of the major national laboratory partners that comprise the JGI whose principal goals are 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 provides the site manager for the Tropical Western Pacific ARM site. LANL also has a crucial role in the development, optimization, and validation of coupled atmospheric and oceanic general circulation models using massively parallel computers. LANL also conducts research into advanced medical imaging technologies for studying brain function including optical imaging and magnetoencepholography, novel radionuclide dosimetry and therapy, and research into new techniques for rapid characterization and sorting of mixtures of cells and cell fragments. 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 National Science Foundation (NSF)/DOE Environmental Molecular Sciences Institute at the 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 LANSCE facility to make fundamental physics measurements (to be completed in FY 2006); the conceptual design and R&D of an experiment to search for the electric dipole moment of the neutron; 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.

Oak Ridge Institute for Science and Education

Introduction

The Oak Ridge Institute for Science and Education, 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 support for education activities.

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 most of the submitted research proposals.

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, the ORO, participating universities, DOE laboratories, and industries.

Science Laboratories Infrastructure

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

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 303 buildings (3.5 million gross square feet of space) with an average building age of 35 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 is under construction and scheduled for commissioning in FY 2006; the High Flux Isotope Reactor (HFIR); and the Center for Nanophase Materials Sciences (CNMS). ORNL has perhaps the most comprehensive materials research program in the country.

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 the mathematics and computer science, as well as research in advanced computing software tools. It also participates in several scientific application partnerships and participates on a number of the SciDAC teams. Integrated Software Infrastructure Center activities are focused on specific software challenges confronting users of terascale 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, a field site for developing and testing bioremediation methods for metal and radionuclide contaminants in subsurface environments.

ORNL is one of the major national laboratory partners that comprise the JGI whose principal goals are high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. 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," which uses mice as model organisms to understand and characterize the human genome. The laboratory conducts research into new instrumentation for the analytical chemistry of complex environmental contamination using new types of biosensors. The laboratory is developing a new experimental station for biological small angle neutron scattering.

High Energy Physics

The HEP program supports a small research effort using unique capabilities of ORNL primarily in the area of particle beam shielding calculations.

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 90 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 ion sources and low energy ion transport for radioactive beams. The capabilities of HRIBF are being augmented by the construction of the High Power Test Laboratory (HPTL) which will provide capabilities which will be unique in the world for the development and testing of new ion source techniques.

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 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. ORNL, in partnership with PPPL, shares responsibility for managing the U.S. ITER Project Office, effective July 2004. ORNL has led the fusion materials science program. This program will be reduced significantly in FY 2007.

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 Office (ORO) 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: PNNL and TJNAF. Oak Ridge also oversees the Oak Ridge Reservation and other DOE facilities in the City of Oak Ridge. Together on the Reservation and in the City of Oak Ridge there are 24 buildings (362,700 square feet) with a total replacement plant value (RPV) of $29.0 million. The RPV of the roads and other structures on the Reservation is $48.2 million. As a result of the recent A-76 competition for financial services, the Oak Ridge Financial Service Center provides payment services for the entire Department of Energy/NNSA, nation-wide. The administrative, business, and technical expertise of Oak Ridge is shared SC-wide through the Integrated Support Center concept. The ORO 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 provides for centralized ORO infrastructure requirements and general operating costs for activities (e.g., roads) on the Oak Ridge Reservation outside plant fences plus DOE facilities in the town of Oak Ridge, PILT, and other needs related to landlord activities.

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.

Office of Scientific and Technical Information

Introduction

The Office of Scientific and Technical Information (OSTI) is located on an 8-acre site in Oak Ridge, Tennessee. The 134,000 square foot OSTI facility houses both Federal and contractor staff; the E-Government infrastructure handling over 15 million downloads and views of DOE's R&D results per year; and over 1.2 million classified and unclassified documents dating from the Manhattan Project to the present. These resources enable OSTI to fulfill its mission to advance science and sustain technological creativity by making R&D findings available and useful to DOE researchers and the American people. OSTI hosts web sites for BER programs and maintains on-line databases.

Safeguards and Security

The S&S program physical security is achieved through a graded protection system including protective forces, security systems, cyber security and program management. The S&S program also incorporates lock and key control, closed circuit television (CCTV), electronic access control and physical access control whereby visitors and employees attain building access via a lobby post where a receptionist is stationed.

Pacific Northwest National Laboratory

Introduction

Pacific Northwest National Laboratory is a multiprogram laboratory located on 132 acres at the Department's Hanford site in Richland, Washington. The laboratory consists of one 8 year old government-owned building (200,000 gross square feet of space). PNNL conducts research in the area of environmental science and technology and carries out related national security, energy, and human health

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 the mathematics and computer science, as well as research in advanced computing software tools. It also participates in several scientific application partnerships, participates on a number of the SciDAC teams, and participates in Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

PNNL is home to the William R. Wiley **Environmental Molecular Sciences Laboratory (EMSL),** a national scientific user facility. PNNL scientists, including EMSL scientists, play important roles in performing environmental remediation sciences research with representation in most areas within that program. PNNL operates the unique ultrahigh field mass spectrometry and nuclear magnetic resonance spectrometry instruments as well as a wide variety of other cutting edge analytical capabilities at the EMSL for use by the national research community.

PNNL provides expertise in research on aerosol properties and processes and in field campaigns for atmospheric sampling and analysis of aerosols. 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 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 charges. It also conducts research into new instrumentation for microscopic imaging of biological systems and for characterization of complex radioactive contaminants by highly automated instruments.

PNNL is one of the major national laboratory partners that comprise the JGI whose principal goals are high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. 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.

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.

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. These programs will be reduced significantly in FY 2007.

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

Introduction

The Pacific Northwest Site Office provides the single federal presence with responsibility for contract performance at PNNL. 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 35 buildings (725,000 gross square feet of space) with an average building age of 30 years. DOE does not own the land.

Advanced Scientific Computing Research

PPPL participates in several SciDAC projects.

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 NSTX, which is an innovative toroidal confinement device, closely related to the tokamak, and has started construction of another innovative toroidal concept, the NCSX, a compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks and the NSF Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas in the U.S. and 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. Through its association with Princeton University, PPPL provides high quality education in fusion-related sciences, having produced more than 185 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

Introduction

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. It also participates in several scientific application partnerships, participates on a number of the SciDAC teams, and participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

SNL provides the site manager for the North Slope of Alaska ARM site. The chief scientist for the ARM-Unmanned Aerial Vehicles (UAV) program is at SNL, and SNL takes the lead role in coordinating and executing ARM-UAV missions. The laboratory conducts advanced research and technology development in robotics, smart medical instruments, microelectronic fabrication of the artificial retina, and computational modeling of biological systems, and fundamental chemistry for the treatment of high-level waste.

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

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. A number of these activities will be reduced in FY 2007. 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 bioimmobilization of heavy metals and radionuclides.

Stanford Linear Accelerator Center

Introduction

The Stanford Linear Accelerator Center (SLAC) is located on 426 acres of Stanford University land in Menlo Park, California, and is also the home of the Stanford Synchrotron Radiation Laboratory (SSRL). The facility is now comprised of 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories, and universities. SLAC (including SSRL) consists of 114 buildings (1.7 million gross square feet of space) with the average age of 29 years. SLAC is a laboratory dedicated to the design, construction, and operation of state-of-the-art electron accelerators and related experimental facilities for use in high-energy physics and synchrotron radiation research. SLAC operates the 2 mile long Stanford Linear Accelerator which began operating in 1966. The SSRL was built in 1974 to utilize the intense x-ray beams from the Stanford Positron Electron Accelerating Ring (SPEAR) that was built for particle physics by the SLAC laboratory. Over the years, SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources.

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 provides major improvements that will increase the brightness of the ring for all experimental stations.

Advanced Scientific Computing Research

SLAC participates on a number of SciDAC teams.

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 serve the 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. All of these facilities make use of the two-mile long linear accelerator, or linac. 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

Introduction

The Stanford Site Office provides the single federal presence with responsibility for contract performance at the Stanford Linear Accelerator Center (SLAC). 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 162 acres (DOE-owned) in Newport News, Virginia focused on the exploration of nuclear and nucleon structure. The laboratory consists of 62 buildings with an average building age of 14 years, 2 state leased buildings, 23 real property trailers, and 10 other structures and facilities totaling over 764,000 gross square feet of space. The laboratory was constructed over the period FY 1987–1995.

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 a user community of ~1,200 researchers and is used annually by ~800 U.S. and foreign 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, will allow 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 as well as for other accelerator projects such as the Spallation Neutron Source.

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

Introduction

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 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Basic Energy Sciences					
Research					
Materials Sciences and Engineering	621,226	746,143	-8,428[ab]	737,715	1,004,212
Chemical Sciences, Geosciences, and Energy Biosciences	232,365	221,801	-1,251[ab]	220,550	268,499
Total, Research	853,591	967,944	-9,679	958,265	1,272,711
Construction	230,025	178,073	-1,781[a]	176,292	148,269
Total, Basic Energy Sciences	1,083,616[c]	1,146,017	-11,460	1,134,557	1,420,980

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 of 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 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.

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,

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006, as follows: Materials Sciences and Engineering (-$7,461,000); Chemical Sciences, Geosciences, and Energy Biosciences (-$2,218,000); and Construction (-$1,780,000).
[b] Reflects a reallocation of funding in accordance with H.Rpt. 109-86, the report for the House-passed Energy and Water Development Appropriations Act, 2006, as follows: Materials Sciences and Engineering (-$967,000); Chemical Sciences, Geosciences, and Energy Biosciences (+$967,000).
[c] Total is reduced by $8,898,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $18,764,000, which was transferred to the SBIR program; and $2,252,000, which was transferred to the STTR program.

and safety of energy generation, conversion, transmission, and use. For example, research on toughened ceramics will result 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 photo conversion 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 Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the mission) plus seven general goals that tie to the strategic goals. The BES program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

The BES program has one program goal which contributes to General Goal 5 in the "goal cascade:"

Program Goal 5.22.00.00: 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 Program Goal 5.22.00.00 (Advance the Basic Science for Energy Independence)

Within the Basic Energy Sciences program, the Materials Science and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram contribute to Program Goal 5.22.00.00 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 (10-year) goals in scientific advancement that the BES program is committed to and that progress can be measured against.

- 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 Program Goal 5.22.00.00 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 micro characterization 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 is also establishing a suite of Nanoscale Science Research Centers that will change 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 contribute 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 5.22.00.00 Advance the Basic Science for Energy Independence (Basic Energy Science)	1,083,616	1,134,557	1,420,980

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 5.22.00.00 Advance the Basic Science for Energy Independence					
Materials Sciences and Engineering					
N/A	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: Demonstrate measurement of 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]	Improve Spatial Resolution: Demonstrate measurement of 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	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: Demonstrate measurement of x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse (>10^8 photons/pulse).[a]	Improve temporal resolution: Demonstrate measurement of x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse (>10^8 photons/pulse).[a]
Chemical Sciences, Geosciences, and Energy Biosciences					
N/A	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]	Improve Simulation: Perform a three-dimensional combustion reacting flow simulation involving more than 30 reacting species and 20 million grid points.	Improve Simulation: Beginning in FY 2007, increasing the size of the simulation will no longer provide useful new information. Thus, this measure is being discontinued.
Materials Sciences and Engineering					
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. [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]	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.

[a] No further improvement is expected in FY 2006–FY 2011 as compared to the level of achievement for FY 2005. Performance levels for resolution (temporal and spatial) have reached the maximum for the current suite of available instruments. 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.

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FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Construction					
Cost and timetables were maintained within 10% of the baselines given in the construction project data sheets 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 data sheets 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 data sheets 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 data sheets for all construction projects ongoing during the year (Results: +0.2% cost variance and -2.5% schedule variance). [Met Goal]	Meet the cost and timetables within 10% of the baselines given in the construction project data sheets for all ongoing construction projects.	Meet the cost and timetables within 10% of the baselines given in the construction project data sheets for all ongoing construction projects.

Means and Strategies

The Basic Energy Sciences 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 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 proposal pressure and scientific workshops; (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 closely coordinated with the activities of 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 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 by which programs can assess their activities differently than by traditional reviews. The BES program has incorporated feedback from OMB and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the BES program a very high 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 found that BES has developed a limited number of adequate performance measures which are continued for FY 2007. 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 Report.

OMB developed PARTWeb for the FY 2007 Budget—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the website http://ExpectMore.gov and will improve public access to PART assessments and follow up actions. For 2006, there are three continuing actions and one new action for Basic Energy Sciences.

- Following up on recommendations of past expert reviews, and using new reviews to assess progress toward long-term programmatic goals.
- The Department will work to include the long-term goals of each program in grant solicitations, and will improve performance reporting by grantees and contractors.
- Improving performance reporting at its user facilities to better reflect the instrumentation and staffing issues most directly connected to scientific output.
- New action—producing a detailed corporate solution for managing and operating the High Flux Isotope Reactor that explicitly addresses the reliability problems while ensuring public health and safety.

In response, BES will continue to use the Committees of Visitors to review progress toward the long term goals of the program and will continue efforts to improve performance reporting. A review of the management and operations of the High Flux Isotope Reactor has been scheduled in 2006 that will address reliability, safety, and health issues. The solution to the reliability problem will be contained in the Basic Energy Sciences report of the review results.

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 Act of 1992.

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, and efficiency, and the mitigation of the adverse impacts of energy production and use. In FY 2005, the program funded research in more than 190 academic institutions located in 48 states and in 13 Department of Energy (DOE) laboratories located in 9 states. BES supports a large extramural research program, with approximately 35% of the program's research activities sited at academic institutions.

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

The 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 micro batteries;
- thermo acoustic 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 we work are given in the sections below.

Advisory and Consultative Activities

Charges are provided to BESAC by the Director of the Office of Science. During the past few years, BESAC has provided advice on new directions in nanoscale science and complex systems; on the operation of the major scientific user facilities; on the need for new, "next-generation" facilities for x-ray, neutron, and electron-beam scattering; on 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/production/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 (1) external, independent review committees operating according to the procedures established for peer review of BES laboratory programs and facilities (http://www.science.doe.gov/bes/labreview.html) and (2) specially empanelled subcommittees of BESAC. These subcommittees have reviewed the synchrotron radiation light sources, the neutron scattering facilities, and the electron-beam micro characterization facilities. The reports of these reviews are available on the BES website (http://www.science.doe.gov/bes/BESAC/reports.html). Regardless of whether a review is by an independent committee charged by a BES program manager or by a BESAC subcommittee charged by the Director of the Office of Science, the review has standard elements. Important aspects of the reviews include assessments of the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; user satisfaction; facility staffing levels; R&D activities to advance the facility; management of the facility; and long-range goals of the facility.

These reviews have identified both best practices and substantive issues, including those associated with mature facilities. For example, the reviews clearly highlighted the change that occurred as the light sources transitioned from a mode in which they served primarily expert users to one in which they served very large numbers of inexperienced users in a wide variety of disciplines. The light sources experienced a quadrupling of the number of users in the decade of the 1990s. This success and its consequent growing pains were delineated by our 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 now under construction.

Facilities that are in design or construction are reviewed according to procedures set down in DOE Order 413.3 “Program and Project Management for Capital Assets” and in the Office of Science “Independent Review Handbook” (http://www.science.doe.gov/opa/PDF/revhndbk.pdf). In general, once a project has entered the construction phase (e.g., the Spallation Neutron Source, the Linac Coherent Light Source, or the Nanoscale Science Research Centers), 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:

(1) Scientific and/or technical merit or the educational benefits of the project;
(2) Appropriateness of the proposed method or approach;
(3) Competency of personnel and adequacy of proposed resources;
(4) Reasonableness and appropriateness of the proposed budget; and
(5) Other appropriate factors, established and set forth by SC in a notice of availability or in a specific solicitation.

In addition, on a rotating schedule, BESAC 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.

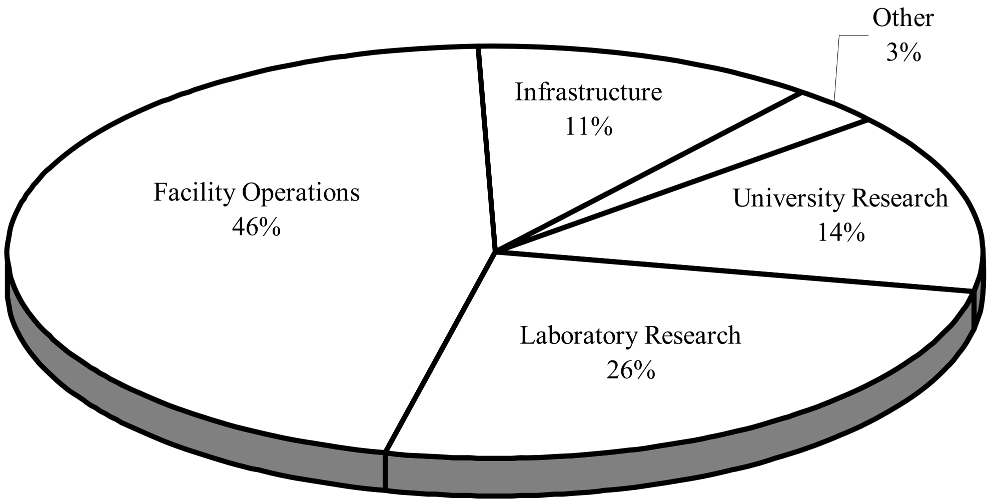
Inputs to our prioritization include overall scientific opportunity, projected investment opportunity, DOE mission need, and Administration and Departmental priorities. During the past few years, these considerations have led to: increased investments in science at the nanoscale to take advantage of the remarkable knowledge gained from atomic-scale understanding of materials; increased investments for operations of the major user facilities in recognition of the quadrupling of users in the past decade and to reap the rewards of the capital investments in the facilities themselves; increased investments for instrumentation at the facilities so that the quality of the instruments will match the world-class quality of the facilities; 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 and basic research for effective solar energy utilization) 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 National Academy of Sciences studies and from broad, national strategies that include the input from multiple federal agencies.

The FY 2007 budget request continues priorities established in the past few years. The Spallation Neutron Source will enter its first 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, Lawrence Berkeley National Laboratory, Argonne National Laboratory and Sandia National Laboratories/Los Alamos National Laboratory. Construction funding is provided for the Nanoscale Science Research Center at Brookhaven National Laboratory. Project Engineering Design and construction funding also are provided for the Linac Coherent Light Source (LCLS), a 4th 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 and spallation neutron sources.

How We Spend Our Budget

The BES program has three major program elements: research, facility operations, and construction and laboratory infrastructure support. Approximately 35% of the research funding goes to support work in universities with most of the remainder going to support work in DOE laboratories. 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 2007 for the Linac Coherent Light Source, the Nanoscale Science Research Center at Brookhaven National Laboratory, and the National Synchrotron Light Source-II. The FY 2007 Request also includes construction funding for the Advanced Light Source (ALS) User Support Building at the Lawrence Berkeley National Laboratory.

Basic Energy Sciences Budget Allocation FY 2007



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 2007, there are a number of significant program milestones and increases, including the following in the area of construction and Major Items of Equipment:

- Construction of the Spallation Neutron Source (SNS) will be completed during the 3rd quarter of FY 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 is funded in FY 2007 that 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 ($10,000,000).
- Four Nanoscale Science Research Centers will be fully operational in FY 2007: 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, and the Center for Integrated Nanotechnologies at Sandia National Laboratories and Los Alamos National Laboratory. A fifth Center, the Center for Functional Nanomaterials at Brookhaven National Laboratory, will receive final year construction funding.
- The Linac Coherent Light Source will continue Project Engineering Design (PED) and construction at the planned levels. Funding is provided separately for preconceptual design and fabrication of instruments for the facility. Funding is also provided to partially support operation of the SLAC linac. This marks the second year of the transition to LCLS operations at SLAC.
- Support is provided for PED ($20,000,000) and Other Project Costs ($25,000,000) for the National Synchrotron Light Source-II (NSLS-II), which will be built as a replacement for NSLS-I, 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 will provide the world's finest capabilities for x-ray imaging.
- Support is provided for PED for the Advanced Light Source User Support Building ($3,000,000), which will provide space for experimental set up 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.

There also are a number of increases in research. In FY 2007, the Office of Science will support expanded efforts in basic research related to transformational energy technologies. This derives from the BESAC workshop report "Basic Research Needs to Assure a Secure Energy Future." Within BES, there are increases to ongoing basic research for effective solar energy utilization, for the hydrogen economy, and for work underpinning advanced nuclear energy power. These are described briefly below. BES not only asks its communities of scientists to provide the scientific foundations to overcome short-term "showstoppers" in energy technologies such as these three, BES also asks researchers to reach far beyond today's problems in order to provide the basis for long-term solutions to what is probably society's greatest challenge—a secure, abundant, and clean energy supply. To that end, there also are increases in research for grand challenge science questions and for new technique development. Grand challenge science includes the study of the fundamental phases of matter and phase transitions; quasiparticles; interactions of strong and weak forces in molecular bonding; "communication" among electrons, atoms, molecules, cells, and organisms; the harnessing of properties of elementary particles, atoms, and molecules to create fundamentally new ways to store, manipulate, and transmit information; and organizing principles at the nanoscopic and mesoscopic scales, intermediate between atomic and macroscopic dimensions. This will be a topic of a forthcoming BESAC workshop.

Briefly, additional research funding is provided in the following areas:

- Basic research for the hydrogen economy. Research to realize the potential of a hydrogen economy will be increased from $32,500,000 to $50,000,000. The research program is based on the BES workshop report "Basic Research Needs for the Hydrogen Economy." The results of the FY 2005 solicitation are described later in this document.
- Basic research for effective solar energy utilization (+$34,115,000). Investments will be focused in three areas: solar-to-electric, solar-to-fuels, and solar-to-thermal conversions. Each of the three generic approaches to exploiting the solar resource has untapped capability well beyond its present usage. Many of the proposed research directions identified in the 2005 BES workshop report "Basic Research Needs for Solar Energy Utilization" concern important cross-cutting issues such as (1) coaxing cheap materials to perform as well as expensive materials in terms of their electrical, optical, chemical, and physical properties (e.g., polycrystalline materials versus expensive single crystal materials or plastics and polymers instead of metals and semiconductors); (2) developing new paradigms for solar cell design that surpass traditional efficiency limits; (3) finding catalysts that enable inexpensive, efficient conversion of solar energy into chemical fuels; (4) identifying novel methods for self-assembly of molecular components into functionally integrated systems; and (5) developing materials for solar energy conversion infrastructure, such as transparent conductors and robust, inexpensive thermal management materials. Powerful new methods of nanoscale fabrication, characterization, and simulation—using tools that were not available as little as five years ago—create new opportunities for understanding and manipulating the molecular and electronic pathways of solar energy conversion.
- Basic research for advanced nuclear energy systems (+$12,432,000). Basic research related to advanced fuel cycles is needed in areas such as (1) control and predictive capability of processes driven by small energy differences, e.g., aggregation and precipitation; (2) fundamental principles to guide ligand design; (3) investigation of new separations approaches based on magnetic and electronic differences; (4) development of environmentally benign separations processes, which produce no secondary wastes and consume no chemicals; and (5) development of modeling of separations processes to optimize waste minimization and minimize opportunities for diversion of nuclear materials (i.e. optimize proliferation resistance). Basic research also is needed in areas of materials for advanced reactors and waste forms for spent fuels from the new generation of reactors. This requires understanding and predicting the properties and behaviors of materials over long time scales and multiple length scales—from atoms to bulk materials. The efficiency, safe operating lifetime, and overall performance of fission energy systems is limited by the load-bearing capacity of structural materials under the maximum temperatures and hostile corrosive, applied stress, and radiation environmental parameters under which they must perform. New generation fission systems require structural materials possessing a combination of properties that will enable them to sustain their performance under such hostile parameters for durations of the order of 100 years.
- Complex systems or emergent behavior (+$5,000,000). Emergent behaviors arise from the collective, cooperative behavior of individual components of a system. Current understanding of emergent behaviors is very limited. The challenge of understanding how emergent behavior results from the complexity of competing interactions is among the most compelling of our time, spanning

physical phenomena as diverse as phase transitions, high temperature superconductivity, colossal magneto resistance, random field magnets, and spin liquids and glasses. Investments will encompass experimental, theoretical, and computational approaches capable of interrogating systems at comparable physical and time scales to gain direct insight into the mechanisms underpinning the cooperative behavior. Unlocking the mysteries of these systems will lay the scientific foundation for designing and engineering new multifunctional materials, devices and sensors with exquisitely sensitive properties.

- Ultrafast science (+$10,000,000). Ultrafast science deals with physical phenomena that occur in the range of one-trillionth of a second (one picosecond) to less than one-quadrillionth of a second (one femtosecond). These phenomena are typically probed using extremely short pulses of coherent light from conventional lasers or free electron lasers such as the Linac Coherent Light Source. Ultrafast technology has applications across the fields of atomic and molecular physics, chemistry and chemical biology, coherent control of chemical reactions, materials sciences, magnetic- and electric-field phenomena, optics, and laser engineering. Examples include the making and breaking of molecular bonds and the observation of the elusive chemical transition state. New investments in ultrafast science will focus on research applications of x-ray sources associated with BES facilities and beamlines: the Linac Coherent Light Source; the femtosecond "slicing" beamline at the Advanced Light Source; and the short pulse development at the Advanced Photon Source. Investments will also be made in the development and applications of laser-driven, table-top x-ray sources, including the use of high-harmonic generation to create bursts of x-rays on the even shorter than the femtosecond time scale.
- Mid-scale instrumentation (+$10,000,000). Scientific progress is predicated on observations of new phenomena, which often involve the building of better tools. There is a significant national need for mid-scale instruments that serve multiple users yet which are not as large as the synchrotron and neutron sources. High priority mid-scale instrumentation needs include end stations at the synchrotron light sources and neutron scattering facilities; laser systems for ultrafast or high-energy-density studies; micro- and atomic-scale characterization tools such as electron microcharacterization and scanning probe microscopy; high-field magnets; and facilities for providing large crystals and other unique materials for researchers throughout the Nation.
- Chemical imaging (+$5,000,000). Investments will develop and apply new methods to measure the chemical behavior of individual molecules and reactions, with high resolution in both space and time in order to elucidate fundamental principles of chemical processes at the nanoscale level. The research will build on current single-molecule spectroscopies and microscopies by adding simultaneous time-dependent characterization of evolving chemical processes, ultimately with femtosecond time resolution.

Additional information on these activities is in the relevant Construction Project Data Sheets and throughout the detailed narrative justifications.

In FY 2007, there are significant shifts in the nanoscale science and engineering research activities contributing to the BES investments in research at the nanoscale and a substantial overall increase in funding. Four of the five planned Nanoscale Science Research Centers are in their first full year of operation, with only one Center still in construction. Overall, the total investment for these Nanoscale Science Research Centers decreases by about 10 percent owing to the planned decrease in construction funding. Funding for research at the nanoscale increases very significantly owing to increases in funding for activities related to the hydrogen economy, solar energy conversion, advanced nuclear energy systems, fundamental studies of materials at the nanoscale, and instrumentation for characterizing materials at the nanoscale.

Nanoscale Science Research Funding

	(dollars in thousands)				
	TEC	TPC	FY 2005	FY 2006	FY 2007
Materials Sciences and Engineering					
Research			65,307	70,328	108,542
Major Item of Equipment, Center for Nanophase Materials (ANL)			12,000	14,000	—
Facility Operations					
Center for Functional Nanomaterials (BNL)			—	—	—
Center for Integrated Nanotechnologies (SNL/A & LANL)			—	11,900	19,190
ORNL, Center for Nanophase Materials Sciences			—	17,800	19,190
Center for Nanophase Materials (ANL)			—	3,500	19,190
Molecular Foundry (LBNL)			—	8,100	19,190
Chemical Sciences, Geosciences, and Biosciences					
Research			27,645	26,914	49,109
Project Engineering Design and Construction					
PED– All sites		21,318	1,996	—	—
Construction					
Center for Functional Nanomaterials (BNL)	79,700	81,000	18,317	36,187	18,864
Center for Integrated Nanotechnologies (SNL/A & LANL)	73,754	75,754	30,650	4,580	247
ORNL, Center for Nanophase Materials Sciences	63,740	64,740	17,669	—	—
Molecular Foundry (LBNL)	83,604	84,904	31,828	9,510	257
Total			205,412	202,819	253,779

In FY 2007, $50,000,000 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 enormous 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 by the three panels 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: (1) novel materials for hydrogen storage, (2) membranes for separation, purification, and ion transport, (3) design of catalysts at the nanoscale, (4) solar hydrogen production, and (5) 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 EERE in the preapplication review process to ensure basic research relevance to technology program goals. Furthermore, BES will participate in EERE's annual program review meeting to promote information sharing and, beginning in FY 2006, will organize parallel sessions at that meeting for the BES principal investigators. 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. The additional $17,500,000 in FY 2007 will be used to augment awards made in FY 2005 and to fund additional proposals based on a new solicitation.

President's Hydrogen Initiative

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Materials Sciences and Engineering Research	14,761	16,600	28,075
Chemical Sciences, Geosciences, and Biosciences	14,422	15,900	21,925
Total Hydrogen Initiative	29,183	32,500	50,000

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. 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 to 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.

The SciDAC program in BES consists of two major 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. The method of choice for the complete characterization of combustion at all scales is direct numerical simulation. A collaboration involving Sandia National Laboratories and four universities successfully implemented a fully parallel implementation of 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 in dealing with the problem of 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 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 percents. They are shown against the project's performance measurement baseline that includes cost and schedule contingency and are as of the end of each fiscal year. All projects have met or are on schedule to meet all Level 0 and Level 1 Milestones, which are shown in the table.

Synchrotron Light Source and Neutron Scattering Facility Operations

	FY 2005 Actual	FY 2006 Estimate	FY 2007 Estimate
All Facilities			
Optimal Hours[a]	30,700	31,300	32,700
Scheduled Hours[b]	28,129	30,610	32,700
Unscheduled Downtime	7.9%	<10%	<10%
Number of Users	9,042	8,050	9,660
Advanced Light Source			
Optimal Hours[a]	5,600	5,600	5,600
Scheduled Hours[b]	5,344	5,520	5,600
Unscheduled Downtime	3.6%	<10%	<10%
Number of Users	2,003	1,770	2,100
Advanced Photon Source			
Optimal Hours[a]	5,000	5,000	5,000
Scheduled Hours[b]	4,931	4,900	5,000

[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 2005 show actual number of hours delivered to users.

	FY 2005 Actual	FY 2006 Estimate	FY 2007 Estimate
Unscheduled Downtime	1.4%	<10%	<10%
Number of Users	3,215	2,640	3,300
National Synchrotron Light Source			
Optimal Hours[a]	5,500	5,400	5,400
Scheduled Hours[b]	5,313	5,030	5,400
Unscheduled Downtime	2.4%	<10%	<10%
Number of Users	2,256	2,070	2,300
Stanford Synchrotron Radiation Laboratory			
Optimal Hours[a]	3,700	5,000	5,000
Scheduled Hours[b]	3,527	4,900	5,000
Unscheduled Downtime	5.0%	<10%	<10%
Number of Users	1,007	980	1,200
High Flux Isotope Reactor			
Optimal Hours[a]	3,400	2,400	4,500
Scheduled Hours[b]	2,613	2,360	4,500
Unscheduled Downtime	23.2%	<10%	<10%
Number of Users	96	100	220
Intense Pulsed Neutron Source			
Optimal Hours[a]	3,600	3,600	3,600
Scheduled Hours[b]	3,462	3,600	3,600
Unscheduled Downtime	4.5%	<10%	<10%
Number of Users	244	240	240
Manuel Lujan, Jr. Neutron Scattering Center			
Optimal Hours[a]	3,900	4,300	3,600
Scheduled Hours[b]	2,939	4,300	3,600
Unscheduled Downtime	23.2%	<10%	<10%
Number of Users	221	250	300
Spallation Neutron Source[c]			

[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 2005 show 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.

Cost and Schedule Variance

	FY 2005 Actual	FY 2006 Estimate	FY 2007 Estimate
Spallation Neutron Source			
Cost Variance	0%		
Schedule Variance	-0.3%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Instrument Systems Design Complete Linac Beam Available to Ring	Ring Beam Available to Target Approve Critical Decision 4 – Start of Operations	N/A
Linac Coherent Light Source (SLAC)			
Cost Variance	0%		
Schedule Variance	-3.9%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 2b – Performance Baseline Approve Critical Decision 3a – Start Long-Lead Procurement	Approve Critical Decision 3b – Start Construction	None
Center for Nanophase Materials Sciences (ORNL)			
Cost Variance	+0.1%		
Schedule Variance	-0.6%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 4a – Start Initial Operations	Approve Critical Decision 4b – Start Full Operations	N/A
Center for Integrated Nanotechnologies (SNL/LANL)			
Cost Variance	-1.2%		
Schedule Variance	-0.3%		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	Approve Critical Decision 4a – Start Initial Operations	Approve Critical Decision 4b – Start of Full Operations
The Molecular Foundry (LBNL)			
Cost Variance	0%		
Schedule Variance	+3.9%		
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
Center for Nanoscale Materials (ANL)			
Cost Variance	+1.2%		
Schedule Variance	-2.6%		
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 2005 Actual	FY 2006 Estimate	FY 2007 Estimate
Center for Functional Nanomaterials (BNL)			
Cost Variance	0%		
Schedule Variance	-26.3%[a]		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 3 – Start Construction	None	Approve Critical Decision 4a – Approve Building Occupancy
Instrumentation for Spallation Neutron Source I (ORNL)			
Cost Variance	-3.1%		
Schedule Variance	-5.1%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 2 for Instruments #1-3 – Performance Baseline Approve Critical Decision 3 for Instruments #1-2 – Start Construction	Approve Critical Decision 2 for Instruments #4-5 – Performance Baseline Approve Critical Decision 3 for Instruments #3 – Start Construction	Approve Critical Decision 3 for Instruments #4-5 – Start Construction

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 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

[a] The significant negative schedule variance for the CFN project is due to the DOE Acquisition Executive's decision to postpone CD-3 approval while BNL extended the procurement process for conventional facilities (CF) to secure a reasonably priced bid. CD-3 was ultimately approved and the CF contract was awarded in late FY 2005. Schedule recovery measures are in place that will ensure that CFN will be completed on time.

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 2007 budget authority of $105,740,000 is requested. The estimated Total Project Cost is $379,000,000. Additional information on the LCLS Project is provided in the LCLS construction project data sheet, project number 05-R-320.

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

The NSLS-II, which is under development, will be a new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will 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 will be the best storage-ring-based synchrotron light source in the world, but, more importantly, NSLS-II will be transformational in that it will 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 will be possible to investigate the atomic and electronic structure and chemical composition of nanometer-scale objects under realistic in-situ device operating conditions. And it will 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 will be unprecedented.

In FY 2007, budget authority is requested to begin Project Engineering and Design and for research and development (R&D) activities 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 Project Engineering Design data sheet, project number 07-SC-06.

Advanced Light Source (ALS) User Support Building Project

The ALS User Support Building to be located at the Lawerence 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 quickly moving the apparatus into place. 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. Additional information on the ALS User Support Building Project is provided in the User Support Building Project Engineering Design data sheet, project number 07-SC-12.

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 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 and also provides talent for a wide variety of technical and industrial areas that require the problem solving abilities, computing skills, and technical skills developed through an education and experience in fundamental research. 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 2005	FY 2006 estimate	FY 2007 estimate
# University Grants	910	810	1,000
Average Size	$150,000	$150,000	$150,000
# Permanent Ph.D.s (FTEs)	4,240	3,900	4,830
# Postdoctoral Associates (FTEs)	1,220	1,140	1,380
# Graduate Students (FTEs)	1,960	1,810	2,170

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been 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 2005	FY 2006	FY 2007
Materials Sciences and Engineering			
Materials Sciences and Engineering Research	290,400	274,220	335,099
Facilities Operations	330,826	444,675	644,885
SBIR/STTR	—	18,820	24,228
Total, Materials Sciences and Engineering	621,226	737,715	1,004,212

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 $338,099,000 research component of this subprogram for FY 2007 are facility related activities such as R&D for new and upgraded facilities, accelerator and detector research, and all BES FY 2007 Major Items of Equipment. These activities total $50,453,000.

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, welding and joining, non-destructive evaluation, electron beam micro characterization, nanotechnology and microsystems, fluid dynamics and heat transfer in materials, nonlinear systems, 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 including new facilities under construction: the Spallation

Neutron Source, the Nanoscale Science Research Centers, the Linac Coherent Light Source, the National Synchrotron Light Source-II, the User Support Building at LBNL, and a number of facility-related Major Items of Equipment.

Selected FY 2005 Research Accomplishments

- Synchrotron X-Rays Demonstrate Nanoscale Ferroelectricity. Films only a few atoms thick have been made that retain the controllable electric polarization needed for next generation nanoscale devices. Such ultrathin ferroelectric films have the potential to revolutionize future electronics, sensors, and actuators. Previous studies suggested that, as devices are miniaturized, they lose their ferroelectric character. These studies showed that ferroelectricity persists in films only 6 atoms thick. This landmark success was achieved using a unique instrument to observe thin film growth with high intensity x-rays from the Advanced Photon Source. X-rays reveal in real time the film structure as it grows, atomic layer by atomic layer. The in-situ x-ray techniques developed for this study can now be used to understand the synthesis and environmental interactions of other complex materials, thus addressing a wide range of energy-related challenges.
- A Superconductor that Tolerates Magnetic Fields. One of the biggest obstacles to the practical use of superconductors is the motion of magnetic flux due to an electric current in a superconductor. This motion of magnetic flux reduced the superconducting properties. A large research effort has gone into finding ways to prevent energy loss occurring from the movement of magnetic flux in copper oxide high temperature superconductors. It has been found that the magnetic flux in certain magnesium diboride films is intrinsically motionless, or “frozen,” in applied magnetic fields up to 14 Tesla. Such a complete apathy to an applied magnetic field has never been seen before in any other superconductor. While the theoretical explanation for this behavior has eluded scientists, the experimental finding has drawn a lot of attention. This behavior may make it possible to fabricate superconducting wire that can carry very large electric currents.
- Using Electron Spin, not Electron Charge, to Carry Information. Today’s computers are based on resistive circuitry using the movement of charged electrons. The resistance generates heat, and the removal of this heat is a fundamental limiting factor in creating the next generation of ultra small and ultra fast circuit elements. In a remarkable discovery, theorists have determined that in certain materials a spin current can be created with the application of a suitably oriented electric field, with no dissipation of energy. The spin current could potentially be used to carry out the same logic operations with no energy loss. This has been verified recently with experiments on gallium arsenide. This discovery may lead to computers with much greater capabilities including speed and capacity due to smaller circuit elements and with a significant reduction in energy loss.
- Plutonium Helps Understand Superconductivity’s Mysteries. Magnetic resonance studies of the fundamental mechanism responsible for superconductivity in $PuCoGa_5$ reveal strong similarities to the high-T_c copper oxide materials. These results confirm earlier theories that this unique family of plutonium superconductors is nearly magnetic. This is a new class of superconducting materials and forms a conceptual bridge between two families of magnetically mediated superconductors, the heavy fermion metals and the copper oxides. The discovery of additional classes of superconducting materials enhances our ability to understand the mechanisms responsible for high temperature superconductivity.
- Ultrafast Studies of Nanocrystals. The fastest phase transition between nanocrystal structures ever recorded has been observed by ultrafast laser techniques. The reversible structural change in nanocrystals of vanadium dioxide switches the material from a semiconductor to a metallic phase,

increasing the electrical conductivity by a factor of 100-10,000 depending on nanoparticle size. Correspondingly large changes from optical transparency to high reflectivity occur at the same time. Lasers with pulses as short as one ten-trillionth of a second were used to track the phase change in vanadium dioxide nanoparticles. This discovery may be key to possible applications requiring extremely rapid switching from transparent to reflective states. These include protective overlayers for sensitive infrared detectors, nonlinear optical switches, fiber-optic pressure sensors, and electrically or optically triggered transistors that could switch hundreds of times faster than conventional silicon devices.

- First Direct Observations of Quasiparticles. Quasiparticles provide a convenient simplification to describe the behavior of electrons in a superconductor. A quasiparticle can be thought of as a single particle moving through a system, surrounded by a cloud of other particles either pushed away or dragged along by its motion. Prior investigations of their dynamics have been indirect. Through the use of a new optical technique it was possible to perform the first direct study of the dynamics of quasiparticles in a superconductor. It was discovered that the quasiparticles can propagate remarkably far, several hundreds of nanometers. Knowledge of the dynamics of quasiparticles, specifically their rates of diffusion, scattering, trapping, and recombination, is critical for the both the applications and fundamental understanding of superconductivity.
- Confining Electrons in New Two-dimensional Materials. Transition metal oxides, like semiconductors, are materials that confine electrons to a plane. It may now be possible to construct near-perfect layered materials of two perovskite structured materials. It has been shown through computational models that a single layer of $LaTiO_3$ in $SrTiO_3$ will serve as an electron donor and positive charge layer to retain those electrons in a thin layer as a two-dimensional electron gas (2DEG). Electrons behaving like a 2DEG appear to be an exotic phenomenon, but they are not. Many semiconductor electronic devices operate by creating just such a gas by an applied electric field inducing a thin conducting region at an interface—the field effect transistor being the prime example. Such thin electron layers have become a valuable tool for scientists studying the ways in which electrons organize their collective behavior. By expanding the materials available to create 2DEGs, new, more diverse opportunities have been created to expand our knowledge of electronic behavior that in turn can produce new applications.
- Inexpensive Route to Solar Cells Using Nanomaterials. New and novel semiconductor nanocrystal-polymer solar cells with surprisingly high efficiencies have been fabricated. In a solar cell, the conversion of light energy to electrical current occurs at the nanometer scale. Thus the development of methods for controlling materials on this scale creates new opportunities for more advanced solar cells. These advances are required because, although solar cells based on silicon and gallium arsenide have achieved high efficiencies and have found a variety of markets, more widespread applications remain limited by their high cost of production. These new cells are formed in an inherently inexpensive process from a colloidal solution of semiconductor nanocrystals in a semiconducting polymer. The unique features of nanosized objects are exploited to optimize the cell performance by controlling the shape of the nanocrystals. The performance of the new cells already rivals that of the best polymer-based devices. While the power conversion efficiency is still below that of current amorphous silicon and single crystal devices, there are opportunities to increase performance further by adding additional nanocrystal components to capture more of the solar spectrum. Furthermore, the same methods can be extended to address other optoelectronic applications, such as photodetectors and light emitting diodes.

- Predicting Magnetism in Nanomaterials. As recording media and sensors become smaller and ever-denser, it is increasingly important to control magnetism in nanostructures. But the physical properties of magnetic nanostructures are linked in complex ways and are difficult to predict, much less control. In this work, the magnetic properties of a cobalt nano-wire next to a platinum surface step were predicted from first-principles. The results are in perfect agreement with experiment and show the importance of a proper quantum mechanical description of the interplay of different magnetic phenomena. This work, based on newly developed quantum mechanical models implemented on high-performance computers, shows that accurate predictions can be made for a nanostructure comprised of a few hundred atoms. With continued theoretical development and more powerful computers, this paves the way toward prediction and control of more complex and useful magnetic structures.
- Explaining Materials Deformation Mechanisms from Atomic-scale Measurements. Using the world's most advanced electron microscope, the first direct observations of atomic details in complex crystalline dislocation cores revealed the atomic mechanisms underlying the deformation of intermetallic compounds with complex crystal structures. It was discovered that the diffusion of chromium atoms into and out of the crystal dislocation cores hinders dislocation motion in Laves-phase Cr_2Hf, a model intermetallic compound, thus providing a clue as to the origin of the brittleness and poor low temperature ductility of these intermetallic alloys. The poor low-temperature ductility of these intermetallic alloys has prevented their fabrication and use for decades. Some of the most attractive high-strength alloys for advanced high-temperature fission and fossil energy conversion applications possess similar complicated atomic configurations and lack the low-temperature ductility required for their fabricated by conventional cold deformation processes without crack formation. This discovery provides new atomistic insight into the behavior of crystal dislocations in complex intermetallic compounds necessary to design new fabricable alloys with the required strength at high service temperatures.
- Discovery of Mechanism of Surface Mass Transport. Researchers have discovered that trace concentrations of sulfur can enhance the rate of mass transport on copper surfaces by many orders of magnitude and have established the atomic scale mechanism by which this enhancement occurs. This discovery was enabled by low-energy electron microscopy measurements of the motion of singe-atom-high steps on copper exposed to calibrated doses of sulfur. By comparing observations of the motion of these steps with theoretical predictions based on calculations of the electronic structure of the surface, this research established that surface mass transport is catalyzed by the formation of a large number of mobile copper sulfide clusters. Such highly mobile clusters are believed to be a common feature of impure surfaces. The enhanced mass transport allows the formation of much flatter and more defect free surfaces. This discovery provides insight to many previous puzzling observations of anomalous surface mass transport. It is an important advance towards the capability to control the nanoscale morphology of surfaces, a critical necessity for nanoscale applications.
- Superior Iron-based Alloys and Steels. Fundamental laws of alloying coupled with advanced microanalytical characterization led to the discovery that yttrium containing iron-based alloys substantially enhance the stability of the amorphous (non-crystalline) state. Two technical implications are: (1) large bulk physical dimensions of this class of amorphous alloys can be made and (2) this understanding provides a new direction for designing bulk amorphous metals for structural and functional applications. Bulk tool steel was fabricated that was twice as hard as conventional tool steel. These achievements are milestones in the science of amorphous metals and

the design of functional complex metallic alloys. Even more important, this research has demonstrated that microalloying is a new approach for designing bulk amorphous alloys. Their unique atomic configurations and the absence of a crystalline lattice allow bulk amorphous metals to outperform their crystalline counterparts by exhibiting superior magnetic and mechanical properties and corrosion resistance coupled with high thermal stability.

- Fracture Resistance Mechanism in Ceramics. Structural ceramics are complex structures of micron-sized matrix grains separated by a nanoscale intergranular film. For many years it has been observed that certain additives, specifically rare-earth atoms, influence the ceramic's fracture resistance. But detailed information about how this effect is achieved and how it can be controlled had been inaccessible with current diagnostic capabilities. Now, new scanning transmission electron microscopy (STEM) and associated chemical analysis techniques have revealed the local atomic structure and bonding characteristics of the grain boundaries with close to atomic resolution. Applied to silicon nitride ceramics containing a range of rare-earth additives, these methods together have revealed how each atom bonds at a specific location depending on atom radius, electronic configuration and the presence of oxygen; this variation in bonding sites can be directly related to the fracture resistance or toughness of the ceramic.
- Better Protective Coatings. Previously unattainable insight into stress development and failure mechanisms in thermally grown surface oxides on metal alloys has been obtained by a new in-situ synchrotron x-ray technique. This technique enabled, for the first time, the uncoupling and isolation of mechanical stress contributions from oxide growth, phase transformations, and creep deformation processes. For pure thermally-grown alumina, steady state oxidation creates compressive stresses. However, when certain "reactive elements" are added to the alloy, it is found that tensile stresses develop instead. Maximizing the tensile offset can lead to dramatic improvement in performance of a protective oxide. A 10 percent shift in the tensile direction can translate to a 40 percent improvement in operating lifetime. Better control of early stage oxidation leads to thinner, and thus longer lifetime protective oxides by speeding the transformation to a stable oxide structure. These results underpin future alloy development for high-temperature nuclear and fossil energy generation technologies and more fuel efficient jet engine applications where operating lifetime has great economic value.
- New Composite Materials that Respond to Magnetic Fields. Magnetic-field-structured composites are a novel class of material in which magnetic particles, dispersed in a polymerizable medium, are organized into chains and other structures by magnetic fields while the polymer solidifies. These chains of particles can be electrically conductive, and this electrical conductivity can be extremely sensitive to temperature, pressure, and chemical vapors that penetrate and swell the polymer. In the present work it was demonstrated that even modest magnetic fields produced by simple copper coils cause these materials to contract significantly, like artificial muscles. This contraction was found to be accompanied by an enormous, 50,000-fold increase in electrical conductivity. This is by far the largest "magnetoresistance" effect ever observed in such modest magnetic fields and paves the way to using magnetic fields to control heat and current transport in micro and nano machines, and to tailoring the sensing response of these materials.
- The "Giant Proximity Effect." The reproducible confirmation of the existence of a Giant Proximity Effect (GPE) has challenged experimentalists for over a decade. In the traditional Proximity Effect (PE), a very thin layer of normal metal, when placed between two thicker superconductor slices, behaves like a superconductor. That is, superconducting or paired electrons retain phase coherence even while separated by the normal metal gap. In the newly discovered GPE, the normal-metal barrier layer is as much as 100 times thicker than in the PE case, a result that stands outside of any

present theories. In addition to challenging the theoretical community and providing new clues to the causes of high-temperature superconductivity, this result may lead to new advances in superconducting circuitry as it is relatively easy to prepare reproducible thick barriers which will improve device uniformity and yield.

- World's Smallest Nanomotor. The smallest synthetic motor—a 300 nanometer gold rotor on a carbon nanotube shaft—has been demonstrated. This "nanomotor" continues the dramatic advances in the miniaturization of electromechanical devices and is a key step in the realization of practical synthetic nanometer-scale electromechanical systems (NEMS). In initial testing, the rotor rotated on its nanotube shaft for thousands of cycles with no apparent wear or degradation in performance. This is attributed to the unique low-friction characteristics of the carbon nanotube shaft. The new motor design has significant potential for NEMS applications. It should be possible to fabricate arrays of orientationally-ordered nanotube-based actuators on substrates by using alignment techniques.
- Magnetohydrodynamic Turbulence in Liquid Metals. Application of a strong magnetic field can completely change flow characteristics of an electrically conducting fluid. The transformation may occur in processes ranging from the generation of sunspots to crystal growth. One particular aspect of this phenomenon, the damping of flow variations along the magnetic field lines and the corresponding development of elongated or even two-dimensional flow structures, affect nearly all aspects of turbulent flow behavior, including heat transfer and mixing. In a series of high resolution numerical experiments it has been shown that the anisotropy of flow (or directionality of flow) patterns is a robust universal feature determined primarily by the strength of the magnetic field, conductivity, and kinetic energy. Furthermore, the elongation of flow patterns is approximately the same for flow structures of different size. This property can be effectively employed for accurate modeling of magnetohydrodynamic turbulence. The results of the work are relevant to technological applications, such as continuous casting of steel, crystal growth, and development of lithium breeding blankets for fusion reactors.
- Nanoparticle Catalysts. Methods were developed for depositing and stabilizing nanometer-sized platinum group metals, including palladium and rhodium, on surfaces of carbon nanotubes in supercritical fluid carbon dioxide. Uniformly distributed monometallic and bimetallic nanoparticles with narrow size distributions are formed on the surfaces of the carbon nanotubes. The carbon nanotube-supported palladium and rhodium nanoparticles demonstrated improved performance over commercial carbon-based palladium and rhodium catalysts for hydrogenation of olefins and aromatic compounds. These new nanoscale catalysts are currently being tested as electrocatalysts for low temperature polymer electrode fuel cells applications.

Selected FY 2005 Facility Accomplishments

- The Advanced Light Source (ALS)
  - Beam-Size Stability Improved. Over the last five years, elliptically polarizing undulators (EPUs) have been used very successfully at the ALS to generate high-intensity photon beams with variable photon polarization (from linear to circular). However, users were not completely satisfied with the EPUs performance because they degraded the beam quality by increasing the photon beam size. Based on detailed magnet measurements, a system was developed that maintains a constant beam size. It is now being employed in routine user operation solving a problem that has affected many other light sources.

- New Undulator Beamline for High-Resolution Photoemission Electron Microscopy. Beamline 11.0.1 is a new elliptically polarizing undulator (EPU) beamline dedicated to photoemission electron microscopy (PEEM) at the ALS. An EPU, the third installed at the ALS, delivers light into the new beamline, which began commissioning March 2005. With full polarization control and continuous coverage optimized over key energy regions, this beamline will be an attractive user facility for organic and magnetic polarization-contrast microscopy. This beamline will have an aberration-corrected photoemission electron microscope (PEEM-3) with a spatial resolution of approximately 5 nanometers.

- New In-Vacuum Undulator Beamline for Femtosecond X-ray Studies. Beamline 6.0.1 for soft x-ray science with ultrashort photon pulses of 200 femtoseconds was ready for commissioning in July 2005. The beamline is unique in the U.S. and will be made available to users in FY 2006. The primary components are a vacuum undulator to produce x-rays over a wide photon-energy range, optical components, including a spectrograph for recording an entire x-ray absorption spectrum from one photon pulse, and a high-repetition-rate femtosecond laser system.

▪ The Advanced Photon Source (APS)

- More Stable Beams. Using a technique pioneered at the APS, 175 girders supporting accelerator components in the APS storage ring have been displaced by as much as 6 mm during scheduled tri-annual maintenance periods over the last seven years, eliminating the stray radiation background signals. As a result, photon beam position monitors (BPMs) for insertion devices over the entire storage ring circumference are now operating on line. The APS leads the world in the use of photon BPMs for insertion device beamlines. Use of these monitors has improved long-term x-ray beam angular stability by more than a factor of five. Users are able to scan the x-ray photon energy by changing the insertion device gap on demand, while still maintaining superior photon beam stability on their samples. The payoff is improved ability to resolve micron and nanometer-sized features in samples

- Improved Timing Experiments. The x-ray pulse structure at the APS is on the order of 100 picoseconds. This pulse width enables special classes of timing experiments where the physical phenomena require fast time resolution. Recent experiments at the APS using this technique have involved the study of porphyrins that may one day form the building blocks of novel catalysts, photonic devices, and efficient solar-power units. The APS has a special operating mode to facilitate these types of measurements. In this mode, a single x-ray timing pulse is isolated from the other x-ray pulses. The intensity in the pulse is determined by the amount of charge stored in the isolated electron bunch that generates the photon pulse. Recent changes to the storage ring top-up injection method, which allows the APS linear accelerator to vary the injection charge along with increasing the injection frequency from two minutes to one minute, have resulted in doubling the single pulse-intensity without adversely affecting the non-timing experiments.

- Improved Mirrors for X-ray Focusing. Elliptically-shaped mirrors based on new technology developed at the Advanced Photon Source are being used to achieve unprecedented focusing of high-brightness x-ray beams. These mirrors are especially useful for producing the microbeams that are used to probe the composition and structure of materials. They are being applied to studies such as microstructural analyses of structural changes arising from welding operations and detailed investigations of the three-dimensional structure of complex crystalline samples.

- Nanoprobe Beamline Commissioned for First Experiments. The world's first hard x-ray nanoprobe was activated in March 2005, at the APS. The Nanoprobe beamline is a central component of the new Center for Nanoscale Materials at Argonne National Laboratory. The x-ray nanoprobe will have a spatial resolution of 30 nanometers or better, the highest of any hard x-ray microscopy beamline in the world. It will offer fluorescence, diffraction, and transmission imaging in the x-ray spectral range of 3-30 keV, making it a valuable tool for studying nanomaterials.

- The National Synchrotron Light Source (NSLS)
  - New X-ray Micro-Diffraction Instrument. This instrument to be used for nanoscale research was developed at the X13B beamline to take advantage of the small source size of the in-vacuum mini-gap undulator in the X13 straight section of the NSLS x-ray ring. It consists of five main subsystems: monochromator, focusing optics, sample manipulator, charge-coupled detector (CCD) area detector, and a point detector with two degrees of freedom. The sample stages are equipped with integrated submicron position encoders for excellent positional precision and repeatability. The point detector assembly allows the use of analyzer crystals to obtain better resolution. A key design feature is the close attention paid to mechanical coupling of the focusing optics to the sample positioner to reduce vibrations and improve the microscope stability for the users.
  - Elliptically-Polarized Wiggler Beamline Upgrade. The Elliptically-Polarized Wiggler (EPW) located in the X13 straight section of the NSLS x-ray is a unique radiation source that produces time-varying elliptically-polarized x-rays for magnetism studies. A major upgrade was performed on beamline X13A to enhance its performance. It included replacement of the existing horizontal focusing mirror, which had been plagued by poor reflectivity as well as mechanical and thermal stability problems, with a new water-cooled spherical mirror. The new mirror system increases the horizontal photon collecting angle by a factor of two and is fully motorized to allow precise manipulation and optimization of the mirror's position. In addition, the beamline interlock and control systems were upgraded. The beamline upgrade has resulted in an order of magnitude increase in the photon intensity delivered to the sample, and the elimination of mechanical and thermal instabilities. These improvements have led to more efficient use of the beamline and increased magnetic sensitivity in the measurements.
  - Development of a Photon-Counting Silicon Microstrip Array Detector. The NSLS detector group has developed an extremely versatile 1-dimensional position sensitive detector. It is based on custom microelectronics developed at Brookhaven National Laboratory, and consists of a linear array of silicon photodiodes, each 0.125 x 4 mm, which is connected to a set of 32-channel custom integrated circuits and a microprocessor system. The detector system's performance is several orders of magnitude better than one can achieve with charge-coupled type detectors. It is easily adaptable to as large an array as is needed by the application. For example, arrays of 320 and 640 strips, 40 and 80mm long have been fabricated for real-time x-ray scattering.
  - X-ray Ring Lattice Symmetry Restored. The most direct benefit for the NSLS user community was the restoration of the x-ray ring magnetic field lattice symmetry, which for many beamlines resulted in a 25 percent reduction of the horizontal beam size and an increase in photon intensity delivered to a sample. The desired eight fold symmetry of the x-ray ring magnet lattice can be lost from errors in the x-ray ring quadrupole field strengths. The quadrupole errors can be partially compensated by trim coils available in the x-ray ring for one of the quadrupole magnet families. These errors were determined from an elaborate analysis of the electron orbit measurements taken as quadrupole magnet field strengths were systematically varied. This

improvement allowed the NSLS to restore the eight fold symmetric x-ray ring magnet settings for routine operations.

- The Stanford Synchrotron Radiation Laboratory (SSRL)
  - First SPEAR3 Run Completed. In the commissioning run for the new SPEAR3 accelerator, the facility proved to be exceptionally reliable, providing very stable beam for a very high percent (97) of the scheduled time. This is higher than ever recorded with SPEAR2, and an exceptional achievement for a new storage ring. The user run commenced in March and the SPEAR3 storage ring operated at 3 GeV/100 mA and provided 30+ hour life times. (The average uptime over the past five years was 96%.) During the run, users on 239 different proposals received beam time in a total of 466 experimental starts involving 1,516 researchers.
  - First High-Current SPEAR3 Tests Performed. SSRL conducted three special 8-hour shifts of SPEAR3 operation with currents above the official safety envelope value of 100 mA. These high-current test shifts took place on swing shifts with the experimental floor cleared of non-radiation workers. The main purpose of these tests was to determine if multi-bunch electron beam instabilities will be encountered at higher current operation, in which case a program to implement a costly multi-bunch feedback system would have to be launched. Other potential problems, primarily excessive component heating, are also of concern. The current reached in these tests was limited to 225 mA by the power rating of some absorbers in a legacy insertion device chamber. This current was reached and a comprehensive search revealed no apparent beam instabilities.
  - New Methods Developed for Studying Structures of Nanomaterials. The reactivity and properties of nanomaterials are highly influenced by particle size and atomic-scale structure. Researchers at SSRL have recently demonstrated that the combined use of several x-ray scattering and absorption measurement techniques leads to quantum leaps in understanding the structures of nanomaterials. X-ray scattering measurements allow experimenters to combine size and shape information with structural information to remove the small-particle size contribution to x-ray diffraction peak broadening, whereas x-ray absorption measurements provide complementary, metal-specific information on local atomic structure in disordered materials. Measurements on zinc sulfide have conclusively demonstrated that structural relaxation of surface atoms causes inhomogeneous internal strain, markedly altering its material properties. This multi-technique nano-characterization approach has further been advanced by developing methods for the routine characterization of bacterial nano-minerals under fully-hydrated *in-situ* conditions. Bacterial nanominerals are an important class of naturally occurring nanomaterials that help to control the composition of the atmosphere, the potability of natural waters, and the arability of soils. This multiple-technique method provides unique information of wide interest to the nanoscience community.
- The Intense Pulsed Neutron Source (IPNS)
  - Simultaneous Measurement of Mixed-conductor Lattice Relaxation, Diffusion, and Gas Conversion. The General Purpose Powder Diffractometer (GPPD) at the IPNS is equipped with a specially designed controlled-atmosphere furnace, where samples in pellet or hollow-tube form are exposed to mixtures of gases to control oxygen and hydrogen content from highly oxidizing to highly reducing environments. Using two separate gas delivery “circuits,” simulated membrane operation conditions can be achieved whereby the responses of oxygen-permeable membranes to strong oxygen partial pressure gradients can be studied. Exhaust gases are

analyzed with a Residual Gas Analyzer to probe for leakage and to quantify gas conversion reactions. Dense ceramic components with mixed-conduction properties and high oxygen permeability are important as membranes for oxygen separation and solid oxide fuel cell applications. Membranes are typically operated at elevated temperatures (800-1000°C) and exposed to large oxygen partial pressure gradients. This experiment reproduces the conditions under which these membranes will be used commercially and provides insights into the unusual differential oxygen partial pressure stability of these materials.

- Accelerator Systems Improvements. Efforts include: completion of the beamline-magnet power supply upgrades, replacing the originals with higher-efficiency and better regulated units; completion of a full year of operation of the first of two new kicker-magnet power supplies; and completion of full-power tests of the new third-rf system that will be installed in the synchrotron ring to provide new proton beam capture and handling capabilities.
- National Neutron and X-ray Scattering School. During August 2005, Argonne National Laboratory again hosted the National School on Neutron and X-Ray Scattering. The school continues to attract outstanding graduate students and post-doctoral appointees with 150 applications for the 60 positions available in 2005. The intensive training introduces students to the theory of, and provides hands-on experimentation in, x-ray and neutron scattering.

▪ The Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE)

- Neutron Scattering Winter Schools. The First and Second Annual LANSCE Neutron Scattering Winter Schools were held, with 30 students from a wide geographical distribution attending each School. The 2004 topic was magnetism and the 2005 topic was mechanical properties of materials. During nine intensive days in Los Alamos, students had lectures from world experts on the key materials issues for the School theme, modeling and theory, and neutron scattering techniques addressing these issues. In addition, the students had the opportunity to gain hands-on experience in neutron-scattering techniques and data analysis.
- New Sample Environments. A major emphasis on sample environments in FY 2005 has greatly enhanced the low temperature, high field, and high pressure possibilities for user experiments. Investments in new low temperature sample environments, high pressure instrumentation, sample goniometers, and support staff have made users more productive. Along with the 11-Tesla superconducting magnet commissioned in 2004, the Lujan Center's suite of sample environments for condensed matter physics has dramatically improved in FY 2005. A rheometer designed to synchronize with the 20 Hz Lujan Center pulsed neutron beam is expected to be tested in FY 2005. It will provide a unique capability to impose accurate hydrodynamic shear on polymer solutions and colloidal suspensions while performing structural measurements by small-angle neutron scattering.
- Instruments Enhancement. The High Intensity Powder Diffractometer (HIPD) and the Single Crystal Diffractometer (SCD) have received upgrades to software, shielding, alignments, and hardware that have increased their neutron intensity, user throughput, and efficiency. New hardware and software controls on the Low-Q Diffractometer (LQD) and a new detector have made small angle neutron scattering (SANS) more effective.

- The High Flux Isotope Reactor (HFIR)
  - Common Guide Casings for Seven New Instruments Installed. Neutron guides transport cold neutrons (energies ~0.1–20 meV) with little loss in flux. This permits one to transport neutron beams from the source to instruments several tens of meters away. This lowers the instrumental background noise from gamma rays and unwanted neutrons since one can place the instruments far from the source. Also, the guides have a slight curvature which removes the "line-of-sight" view of the neutron source and further reduces this background. The guides are made by coating glass with layered coatings called supermirrors which are highly reflective for neutrons. These flat, coated glass plates are then assembled to form hollow rectangular cross-sectioned pipes with the coated sides forming the interior walls of the pipes. These guides will be illuminated with neutrons produced by the new HFIR cold source to be installed early in 2006.
  - HB-4 Shield Tunnel and Velocity Selector Shielding Installed. A great deal of neutron shielding is required to shield the exit of the new HFIR cold source and components of the cold neutron beamlines. The first and largest general section of shielding for the new instruments was constructed. Also, the lead shielding for the velocity selectors for the two small angle neutron scattering (SANS) instruments was assembled. These components are essential for the new Center for Neutron Scattering cold neutron spectrometers.
  - SANS 1 Detector Tank and Internal Components Installed. The largest component for the first Small Angle Neutron Scattering (SANS) instruments has been installed. This giant tank will contain the detector for this instrument. The 1 meter square detector will ride on rails inside the evacuated volume of the tank.
  - The Neutron Reflectometer Commissioned. A new instrument, the neutron reflectometer, was commissioned for use in the general user program at the HFIR Center for Neutron Scattering. This machine is optimized for the studies of surfaces and interfaces. It is the fifth Cold Neutron Source instrument fully commissioned and will be used for the studies of polymers, biomaterials, thin solid films, and surfactants.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Materials Sciences and Engineering Research	**290,400**	**274,220**	**335,009**
▪ **Structure and Composition of Materials**	**24,907**	**16,943**	**22,245**

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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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 2007, 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 are increases to support the development of advanced electron microscopy and scanning probe techniques ($+763,000), ultrafast electron scattering probes as companion tools to ultrafast photon probes ($+1,000,000), for mid-scale instrumentation to develop new experimental tools and techniques for atomic scale structural characterization ($+2,000,000), for research related to the hydrogen economy ($+100,000), and for solar energy conversion ($+1,439,000).

	FY 2005	FY 2006	FY 2007
▪ **Mechanical Behavior and Radiation Effects**	**14,008**	**13,037**	**18,195**

This activity supports basic research to understand the deformation, embrittlement, fracture, and radiation damage of materials. Concerns include the behavior of materials under repeated or cyclic stress, high rates of stress application as in impact loading, and over a range of temperatures corresponding to the stress and temperature conditions in present and anticipated future 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 in order to develop predictive models for the design of materials having superior mechanical behavior, with some emphasis on very high temperatures. The focus of basic research in radiation effects is to achieve an atomic-level fundamental understanding of mechanisms of radiation damage and how to design radiation-tolerant materials. Concerns include radiation induced embrittlement and radiation assisted stress-corrosion cracking. Other issues 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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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 2007, 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 for ongoing materials research in support of materials related to advanced nuclear reactor fuel cycles ($+5,158,000).

	FY 2005	FY 2006	FY 2007
▪ **Physical Behavior of Materials**	**25,551**	**24,677**	**29,756**

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 critical.

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 2007, 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 are increases to support solar conversion research ($+4,379,000) and research activities related to the hydrogen economy ($+700,000).

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Synthesis and Processing Science**	**15,149**	**17,083**	**21,022**

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 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 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 2007, 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 in ways 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 initiate new emergent behavior research ($+1,000,000), research activities related to hydrogen economy ($+1,500,000), and solar energy conversion ($+1,439,000).

▪ **Engineering Research**	**5,306**	**2,444**	**1,000**

This activity supports fundamental atomic or nanoscale 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.

The performance, safety, and economics of fission, fusion, fossil, and transportation energy conversion systems depend on a thorough understanding of heat transfer in regimes of complex, multi-phase fluid flow and the ability to provide reliable early warning of impending catastrophic fracture or other failure.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

In FY 2007, in order to emphasize other research activities described herein, selected activities in engineering research will be terminated, including nanoindentation, fluid behavior during solidification, heat transfer, and multiphase fluid flow.

▪ **Neutron and X-ray Scattering**	**46,061**	**45,141**	**62,055**

This activity supports basic research in condensed matter physics and materials physics using neutron and x-ray scattering capabilities, primarily at major BES-supported user facilities. Research seeks to achieve a fundamental understanding of the atomic, electronic, and magnetic structures of materials as well as the relationship of these structures and excitations to the physical properties of materials. The increasing complexity of such energy-relevant materials as 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, together with the electron scattering probes 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 2007, activities will be initiated in ultrafast materials science research with an emphasis on understanding the physics of strongly correlated systems and systems at the nanoscale; properties and behavior of materials at high pressure magnetic fields; real-time, in-situ characterization of materials synthesis; exploratory research on next generation instrument concepts for synchrotron light sources and neutron sources; and studies of structure and dynamics in hydrogen storage materials ($+9,614,000). Additional funding is provided for the development of new research activities in photon-based ultrafast materials science ($+4,000,000), the development of mid-scale instrumentation including end stations at the synchrotron light sources and neutron scattering facilities ($+1,000,000), and research related to the hydrogen economy ($+2,300,000).

▪ **Experimental Condensed Matter Physics**................................	**41,024**	**36,691**	**47,480**

This activity supports condensed matter physics with emphases in electronic structure, surfaces, and 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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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 which underpin various technology programs in Energy Efficiency and Renewable Energy (EERE). Research in superconductivity and photovaltaics especially 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. The petroleum recovery efforts of Fossil Energy (FE) and the clean-up efforts of Environmental Management (EM) programs are supported through research on granular materials and on fluids.

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

In FY 2007, 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 initiate mid-scale instrumentation for the synthesis of new materials and the growth of high quality single crystals ($+2,500,000) and for solar energy conversion ($+4,939,000). Additional funding is provided for research related to the hydrogen economy ($+3,350,000).

	FY 2005	FY 2006	FY 2007
▪ **Condensed Matter Theory**	**19,798**	**22,888**	**27,408**

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. Examples include fracture mechanics—

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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 2007, major activities will include both 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 lay the scientific foundation for designing and engineering new multifunctional materials, devices and sensors with exquisitely sensitive properties. Within this funding, there are increases to support new emergent behavior research ($+1,500,000), research related to hydrogen production, storage, and use ($+1,100,000), and for solar energy conversion ($+1,920,000).

	FY 2005	FY 2006	FY 2007
▪ **Materials Chemistry**	**46,860**	**40,694**	**49,748**

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 (NMR), 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 2007, major activities will include the 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

inorganic/organic components in engineered assemblies with unprecedented efficiencies for the conversion of solar photons to fuels and chemicals. Within this activity, there are increases for direct solar conversion to fuels research ($+5,129,000) and for the development of new tools, techniques and mid-scale instrumentation to measure forces, atomic configuration, and physical and chemical properties with ultrahigh sensitivity to further advance nanoscale science ($+1,500,000). Additional funding is provided for research related to the hydrogen economy ($+2,425,000).

	FY 2005	FY 2006	FY 2007
▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**	**7,643**	**7,280**	**8,000**

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, Nevada, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, 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, and nuclear physics, fusion energy sciences, fossil energy sciences, and energy efficiency and renewable energy sciences. In FY 2007, funding is increased for EPSCoR research activities ($+720,000). The following table shows EPSCoR distribution of funds by state.

EPSCoR Distribution of Funds by State

	FY 2005	FY 2006	FY 2007
Alabama	695	685	258
Alaska	—	—	—
Arkansas	145	135	139
Delaware	—	—	—
Hawaii	—	—	—
Idaho	476	375	375
Kansas	626	135	—
Kentucky	224	—	—
Louisiana	660	462	375
Maine	—	—	—
Mississippi	667	132	—
Montana	375	455	133
Nebraska	120	265	269
New Hampshire[a]	—	—	—
Nevada	—	90	105
New Mexico	135	135	—
North Dakota	406	273	—
Oklahoma	485	350	350
Rhode Island[a]	—	—	—

[a] Becomes eligible in FY 2006.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Puerto Rico	375	375	—
South Carolina	716	660	525
Tennessee	125	125	—
Vermont	—	140	140
U.S. Virgin Islands	705	—	—
West Virgina	—	—	—
Wyoming	315	225	135
Technical Support	270	140	140
Other[a]	123	60	110

- **Electron-beam Microcharacterization** **7,614** **7,945** **7,945**

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 on 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 2007, user operations, scientific research of the staff, and development of new instruments or techniques will continue to be supported at the electron beam microcharacterization user facilities.

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[a] Uncommitted funds in FY 2006 and FY 2007 will be competed against among all EPSCoR.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Accelerator and Detector Research**	**4,000**	**2,119**	**3,000**

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 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 in order to achieve high power spallation sources. There is also joint interest in collaboration with NSF on Energy Recovery Linac (ERL) research. There is a coordinated effort between the DOE and NSF to facilitate the development of x-ray detectors. There are ongoing industrial interactions through the SBIR/STTR awards for the development of x-ray detectors.

In the area of neutron science, there is research to develop improved high intensity, low emittance proton sources for accelerator-driven neutron sources. More efficient proton sources can increase the reliability and lifetime due to lower RF power requirements.

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 2007, activities in novel accelerator and source concepts as well as detector research will continue.

▪ **General Plant Projects**	**3,250**	**—**	**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**	**2,000**	**—**

Capital Equipment funding for new and upgraded instrumentation prior to the installation and commissioning of the cold source has been competed.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Linac Coherent Light Source (LCLS)**	**4,000**	**—**	**—**

Research and development (R&D) funds were provided to support the physics design of several key LCLS components: the photocathode gun, the linac, the undulator, and the beam optics. These R&D activities were carried out at SLAC and other collaborating institutions in order to reduce the technical risk and provide more confidence in the project's cost and schedule estimates prior to establishing a project performance baseline. No funding is requested in FY 2006 or FY 2007.

▪ **Nanoscale Science Research Centers**	**600**	**993**	**500**

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

▪ **The Center for Nanoscale Materials**	**12,000**	**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, including clean rooms, 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 which 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 be the highest spatial resolution instrument of its kind in the world, which will permit nondestructive examination of magnetic, electronic, and photonic materials important both for basic science and as foundations for future nanotechnologies.

▪ **Spallation Neutron Source Instrumentation I**	**3,143**	**12,579**	**10,500**

Funds are provided to continue a Major Item of Equipment with a total estimated cost of $68,500,000 for five instruments for the Spallation Neutron Source that will be installed after the SNS line item project is completed in FY 2006. These instruments will complement the initial suite of five instruments that are being built as part of the SNS construction project, which has capacity for 24 instruments. The instrument concepts for the Major Item of Equipment project were competitively selected using a peer review process. The project will be managed by Oak Ridge National Laboratory with participation by both Argonne and Brookhaven National Laboratories as well as by the State University of New York at Stony Brook. The instruments will be installed at the SNS on a phased schedule between FY 2007 – 2011. A new Major Item of Equipment, described below, will fund approximately four to five additional instruments.

▪ **Research on Instrumentation for the Linac Coherent Light Source (LCLS)**	**1,900**	**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.

▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	**5,586**	**6,206**	**5,508**

Funds are provided for a Major Item of Equipment with a Total Estimated Cost in the range of $11,200,000 to $13,500,000 and a Total Project Cost in the Range of $25,000,000 to $30,000,000. The TEAM project will construct and operate a new aberration-corrected electron microscope and make this capability widely 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 2005	FY 2006	FY 2007
▪ **Linac Coherent Light Source Ultrafast Science Instruments (LUSI)**	—	—	**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 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 close 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 Complex. The TEC 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 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 2005	FY 2006	FY 2007
▪ **Spallation Neutron Source Instrumentation II**	—	—	**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 approximately five instruments for the Spallation Neutron Source that will be installed after the SNS line item project is completed in FY 2006. These instruments will effectively complete the suite of instruments 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.

	FY 2005	FY 2006	FY 2007
Facilities Operations	**330,826**	**444,676**	**644,885**
▪ **Operation of National User Facilities**	**330,826**	**444,676**	**644,885**

The operations of the scientific user facilities are funded at a level that will permit service to users at optimal capacity, an increase from FY 2006. 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 second year of a transition of programmatic ownership for SLAC linac operations from HEP to BES as the LCLS project proceeds. FY 2007 funding is requested for National

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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 2005 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 (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.

Facilities

	FY 2005	FY 2006	FY 2007
Advanced Light Source	44,800	42,783	49,802
Advanced Photon Source	100,500	95,890	108,604
National Synchrotron Light Source	36,750	36,196	40,763
National Synchrotron Light Source-II	1,000	—	25,000
Stanford Synchrotron Radiation Laboratory	32,388	25,475	35,836
High Flux Isotope Reactor	46,900	43,330	51,598
Radiochemical Engineering Development Center	4,500	—	—
Intense Pulsed Neutron Source	16,800	15,500	18,531
Manuel Lujan, Jr. Neutron Scattering Center	9,588	10,000	10,582
Spallation Neutron Source	37,600	101,001	171,409
Center for Nanophase Materials Sciences	—	17,800	19,190
Center for Integrated Nanotechnologies	—	11,900	19,190
Molecular Foundry	—	8,100	19,190
Center for Nanoscale Materials	—	3,500	19,190
Linac Coherent Light Source (LCLS)	—	3,500	16,000
Linac for LCLS	—	29,700	40,000
Total, Facilities	330,826	444,675	644,885

SBIR/STTR	**—**	**18,820**	**24,228**

In FY 2005, $13,551,000 and $1,626,000 were transferred to the SBIR and STTR programs, respectively. The FY 2006 and FY 2007 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

Total, Materials Sciences and Engineering	**621,226**	**737,715**	**1,004,212**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Materials Sciences and Engineering Research	
▪ **Structure and Composition of Materials**	
Increases are provided for developing advanced electron microscopy and scanning probe techniques ($+763,000), research to advance the hydrogen economy ($+100,000), ultrafast science ($+1,000,000), mid-scale instrumentation ($+2,000,000), and solar energy conversion ($+1,439,000)	+5,302
▪ **Mechanical Behavior and Radiation Effects**	
Increase is provided for ongoing research in support of materials related to advanced nuclear reactor fuel cycles	+5,158
▪ **Physical Behavior of Materials**	
Increases are provided for research to advance the hydrogen economy ($+700,000) and solar energy conversion ($+4,379,000).	+5,079
▪ **Synthesis and Processing Science**	
Increase is provided for emergent behavior ($+1,000,000), research to advance the hydrogen economy ($+1,500,000), and solar energy conversion ($+1,439,000)	+3,939
▪ **Engineering Research**	
Termination of selected activities in engineering research including fluid behavior during solidification and heat transfer	-1,444
▪ **Neutron and X-ray Scattering**	
Increases are provided for research and instrumentation for studies of strongly correlated materials, systems at the nanoscale, materials in high fields, and other studies relevant to energy needs ($+9,614,000). Increases are also provided for research to advance the hydrogen economy ($+2,300,000), ultrafast science ($+4,000,000), and mid-scale instrumentation ($+1,000,000)	+16,914
▪ **Experimental Condensed Matter Physics**	
Increases are provided for research to advance the hydrogen economy ($+3,350,000), mid-scale instrumentation ($+2,500,000), and solar energy conversion ($+4,939,000)	+10,789
▪ **Condensed Matter Theory**	
Increases are provided for research to advance the hydrogen economy ($+1,100,000), emergent behavior ($+1,500,000), and solar energy conversion ($+1,920,000)	+4,520

	FY 2007 vs. FY 2006 ($000)
▪ **Materials Chemistry**	
Increases are provided for research to advance the hydrogen economy ($+2,425,000), mid-scale instrumentation ($+1,500,000), and solar energy conversion ($+5,129,000)	+9,054
▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**	
Increases is provided for additional EPSCoR research activities	+720
▪ **Accelerator and Detector Research**	
Increase is provided for additional research in new accelerator and detector concepts, including accelerator concepts for light sources not necessarily based on storage-ring technologies	+881
▪ **General Plant Projects**	
Increase is provided for general plant projects as part of the BES stewardship responsibilities	+737
▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	
Funding for new and upgraded instrumentation prior to installation and commissioning of the cold source is complete..	-2,000
▪ **Nanoscale Science Research Centers**	
Scheduled decrease for Other Project Costs for the Nanoscale Science Research Centers. Funding is provided for Other Project Costs for the BNL Center for Functional Nanomaterials. No Other Project Costs are required for the remaining Nanoscale Science Research Centers	-493
▪ **The Center for Nanoscale Materials**	
Scheduled decrease for the Major Item of Equipment for the ANL Center for Nanoscale Materials due to its completion	-14,000
▪ **Spallation Neutron Source Instrumentation I**	
Scheduled decrease for Instrumentation for the Spallation Neutron Source.	-2,079
▪ **Research on Instrumentation for the Linac Coherent Light Source (LCLS)**	
Scheduled decrease for R&D on instrumentation for the LCLS	-1,500
▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	
Scheduled decrease for the Major Item of Equipment for the Transmission Electron Aberration Corrected Microscope	-698
▪ **Linac Coherent Light Source Ultrafast Science Instruments (LUSI)**	
Initiate Major Item of Equipment for approximately four instruments at the Linac Coherent Light Source.	+10,000

	FY 2007 vs. FY 2006 ($000)
▪ **Spallation Neutron Source Instrumentation II**	
Initiate a new Major Item of Equipment for approximately four to five additional instruments for the Spallation Neutron Source	+10,000
Total, Materials Sciences and Engineering Research	**+60,879**
Facilities Operations	
▪ **Operation of National User Facilities**	
Increase for the Advanced Light Source to support accelerator operations and for increased support for users	+7,019
Increase for Advanced Photon Source to support accelerator operations and for increased support for users	+12,714
Increase for National Synchrotron Light Source to support accelerator operations and for increased support for users	+4,567
Increase for National Synchrotron Light Source-II – Other Project Costs per FY 2007 project data sheet	+25,000
Increase for the Stanford Synchrotron Radiation Laboratory to support accelerator operations and for increased support for users	+10,361
Increase for High Flux Isotope Reactor to support reactor operations	+8,268
Increase for Intense Pulsed Neutron Source to support accelerator operations and for increased support of users.	+3,031
Increase for the Manuel Lujan, Jr., Neutron Scattering Center to support target operations and for increased support for users	+582
Increase for Spallation Neutron Source to support operations in the first full year of operation.	+70,408
Increase for the Center for Nanophase Materials Sciences for continued operations.	+1,390
Increase for Center for Integrated Nanotechnologies for continued operations	+7,290
Increase for Molecular Foundry for continued operations.	+11,090
Increase for Center for Nanoscale Materials for continued operations.	+15,690
Increase for Linac Coherent Light Source Other Project Costs per FY 2007 project datasheet.	+12,500
Increase for Stanford Linear Accelerator Center in support of the linac operations	+10,300
Total, Facilities Operations	**+200,210**

	FY 2007 vs. FY 2006 ($000)
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in total operating expense...........	+5,408
Total Funding Change, Materials Sciences and Engineering	**+266,497**

Chemical Sciences, Geosciences, and Energy Biosciences

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Chemical Sciences, Geosciences, and Energy Biosciences			
Chemical Sciences, Geosciences, and Energy Biosciences Research	225,928	208,831	255,113
Facilities Operations	6,437	6,251	6,805
SBIR/STTR	—	5,468	6,581
Total, Chemical Sciences, Geosciences, and Energy Biosciences	232,365	220,550	268,499

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 $255,113,000 research component of this subprogram is support for General Plant Projects and General Purpose Equipment totaling $17,466,000.

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 provides support for chemistry comparable to that of the National Science Foundation. It 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 2005 Research Accomplishments

- Timing the World's Shortest X-Ray Pulses. Light sources based on particle accelerators, such as the Linac Coherent Light Source (LCLS), will revolutionize x-ray science due to their unprecedented brightness and extremely short pulse duration. To take full advantage of x-ray pulses that last only a few femtoseconds (10^{-15} seconds), they must be timed relative to equally short pulses from an optical laser. Such measurements are vital to a wide range of LCLS experiments in which a sample is excited by an optical pulse and probed by an x-ray pulse. At the Stanford Linear Accelerator Center, ultrashort x-ray pulses were generated when 80-femtosecond electron pulses from an accelerator were sent through an undulator magnet; the x-ray and electron pulses were perfectly coincident in time. A crystal placed near the path of the electron beam experienced intense electric fields that altered the optical properties of the crystal, the electro-optic (EO) effect. An optical laser beam passing through the crystal sensed the EO effect, turning the time delay between the optical pulse and the electron/x-ray pulse into a spatial displacement on a detector. The current timing resolution of 60 femtoseconds could be improved to 5 femtoseconds, matching the projected performance of accelerator-based light sources into the foreseeable future.
- Molecular Fragmentation Observed in Unprecedented Detail. Researchers working at the Advanced Light Source have advanced our ability to observe the total destruction of a molecule to new levels of sophistication, challenging theoretical understanding and paving the way for research to be performed at next-generation light sources. When a hydrogen molecule is exposed to x-ray photons of the appropriate energy, the two electrons it possesses can be ejected at once, leaving behind two positively charged nuclei that rapidly explode. Thus, absorption of one x-ray photon causes the complete destruction of the molecule. Using modern techniques of three-dimensional imaging and ultrafast timing, the motions of all four particles from a single event can be related to one another. The results are surprising and challenge our current theoretical understanding of how x-rays interact with matter.
- Complete Ionization of Clusters in Intense VUV Laser Fields. BES-supported researchers have developed a theory that explains recently-observed ionization behavior of xenon clusters that were exposed to intense, coherent vacuum ultraviolet (VUV) pulses from a free-electron laser (FEL). Surprisingly, at intensities that produce only single ionization of an isolated xenon atom, the clusters irradiated by the FEL showed massive ionization in which every atom in the cluster was highly ionized, producing ions with charge states up to +8. This implies that each xenon atom in the cluster absorbed about 30 VUV photons. The key difference between clusters and isolated atoms is that energetic electron-ion collisions occur within the clusters and modify the single-photon absorption cross section, thus allowing a large number of photons to be absorbed. This process is called "inverse bremsstrahlung" and, when incorporated into a simple linear absorption model, clearly reproduces the experimental observations. Theories such as this will be needed to understand the behavior of matter when it is exposed to intense, coherent X-ray pulses from next-generation light sources such as the LCLS.
- The Roaming Atom: Straying from the Lowest-energy Reaction Pathway. A fundamental tenet of modern chemical reaction theory is the concept of the transition state, a transient molecular entity

that lies on the most direct pathway from reactants to products and whose properties govern the rate of reaction. Recently, it was shown that in a simple chemical reaction, the decomposition of formaldehyde, a substantial fraction of the dissociating molecules avoid the region of the transition state entirely. These studies combine ion imaging experiments with theoretical trajectory calculations to reveal that the dissociation takes place via a mechanism in which one hydrogen atom begins to roam away from the molecule and nearly dissociates, then returns to react with the remaining hydrogen atom. Along with other recent findings on reactions such as $O + CH_3$, these results challenge conventional notions of chemical reactions and raise the question of how common such processes might be. A key question is whether such a mechanism applies only to reactions forming hydrogen, during which a light hydrogen atom may rapidly explore regions far from the conventional transition state.

- New Combustion Intermediates Discovered. A complete mechanism for the combustion of simple hydrocarbon fuels includes dozens of distinct molecular species and hundreds of chemical reactions. The identification of which molecules to include in a combustion chemistry mechanism still requires experimental detection, particularly for reactive intermediates. A class of unstable molecules known as enols, which have OH groups adjacent to carbon-carbon double bonds, are not currently included in standard combustion models. In work performed at the Advanced Light Source, significant quantities of 2, 3, and 4-carbon enols were observed using photoionization mass spectrometry of flames burning representative compounds from modern fuels. Concentration profiles of the enols taken in the model flames demonstrate that their presence cannot be accounted for by isomerization reactions that convert more stable molecules into enols. This leads to the conclusion that an entire class of important reaction intermediates is absent from current combustion models, and the models will need substantial revision.
- Unified Molecular Picture of the Surfaces of Aqueous Solutions. A long-term controversy exists regarding the detailed, molecular nature of the surface of an aqueous solution containing molecular ions (or electrolytes). Joint theoretical and experimental studies have led to a new, unified view of the structure of the interface between air and aqueous electrolytes. Molecular dynamics simulations have shown that in basic salt solutions positively charged ions (cations) are repelled from the interface, while negatively charged ions (anions) exhibit a propensity to migrate toward the surface that correlates with the anion's polarizability and physical size. In acidic solution, however, there is a high propensity for cations to be located at the air/solution interface. In this case, both cations and anions are concentrated at the surface and reduce the surface tension of water. These conclusions have been verified by surface-selective nonlinear vibrational spectroscopy experiments. Understanding the behavior of ions at aqueous surfaces is important to the heterogeneous chemistry of seawater aerosols and to the tropospheric ozone destruction in the Arctic and Antarctic due to reactions on ice pack covered with sea spray.
- Self-Assembled Artificial Photosynthesis. In natural photosynthesis, self-assembly of light-absorbing molecules, or chromophores, at specific distances and orientations is especially important in two parts of the overall photosynthetic system: the antenna component, where light is collected; and the reaction center, where charge is separated. Recently, a green organic chromophore was discovered that exhibits photophysical and photoredox properties similar to those of natural chlorophyll a. When conjoined with four similar chromophores, the molecules self-assemble in solution to form an antenna-reaction center complex. Self-organization of the large structure is believed due to the propensity of these similar chromophores to align in a cofacial stacking arrangement. The self-

assembled organic has attributes that closely mimic the primary events in photosynthesis: efficient light energy capture over a wide spectral range, energy funneling toward a core electron-transferring unit, and excited-state symmetry breaking of a molecular pair resulting in charge separation. The structure of the new array was determined at the Advanced Photon Source.

- Two-Dimensional Spectroscopy Reveals Energy Transport Pathways In Photosynthesis. Photosynthetic antennas capture solar photons and transport the absorbed energy to the photosynthetic reaction center where charge separation occurs. Energy transfer by the antenna is nearly 100 percent efficient, although the mechanism for the process has been elusive. A novel spectroscopic technique known as a two-dimensional photon echo, commonly used in the infrared, has been extended to the visible spectral region and has revealed important details about energy transfer in photosynthetic light harvesting. In antenna pigments from green sulfur bacteria, distinct energy transport pathways have been identified that depend on the spatial properties of the pigment-protein complex. Contrary to the accepted model of a sequential cascade in energy from high- to low-lying excited states, these results reveal excited states that are distributed over two or more chlorophyll molecules and a pathway in which energy levels are skipped on the way to the lowest level. The new two-dimensional electronic spectroscopic method, which measures electronic couplings and maps the flow of excitation energy, opens the door to investigation of other photoactive systems and can be applied to improving the efficiency of molecular solar cells.
- How Water Networks Accommodate an Excess Electron. In bulk water an excess electron can become trapped within a cavity formed by a network of hydrogen-bonded water molecules. This "solvated electron" is a critical chemical intermediate in the radiolysis of aqueous solutions. One approach to understanding the solvated electron is to study the structure and dynamics of clusters of water containing an excess electron in the gas phase. This approach has not yet been successful because these anionic water clusters are hard to make and because an accurate theoretical description for them is lacking. Recent work has shown that anionic clusters containing four to six water molecules can be created within gas-phase matrices of inert argon clusters, where their infrared spectra can be obtained. Analysis of these spectra using density functional theory shows that the diffuse electron interacts most strongly with a single water molecule that is hydrogen bonded to two other waters in a rearranged network. The spectra also exhibit evidence for the rapid exchange of energy between the vibrations of the hydrogen atoms on the unique molecule and the excess electron. This new technique can now be extended to larger water clusters that better mimic the solvated electron in bulk water.
- Gold, a Magnificent Nanoscale Catalyst. When gold atoms are assembled as tiny clusters smaller than 8 nanometers and attached to the surface of titanium oxide, they acquire the remarkable ability to dissociate oxygen at room temperature and insert that oxygen into very specific locations in molecules. The origin of such unusual reactivity—discovered some 10 years ago—has until recently evaded a widely accepted explanation. Numerous parameters in the material are important and usually cross-correlated: gold particle dimension and shape, metal oxidation state, oxide support reducibility, and interaction of the gold with the support. Separating those parameters in these materials, which are macroscopically amorphous, would demand special analytical techniques that are able to focus on the detailed properties of individual chemical bonds in the solid. Therefore, researchers pursued a different route using existing and well-known surface science techniques: they accurately synthesized and stacked one-atom-thick layers of gold extended in two dimensions, and supported them on top of perfect oxide crystals of known structure. They demonstrated that the

nanoscale properties of gold metal are achievable by controlling the layer thickness to between 2 and 3 atoms. Such knowledge can now be extended to the manipulation of selective oxidation chemistry or the discovery and assembly of new catalysts.

- Theory Guides Scientists on How to Extract Hydrogen from Natural Sources and Store it Efficiently. Two of the keys to a hydrogen economy are having an abundant supply of hydrogen and having materials that can store such hydrogen in a readily accessible form. Both of those challenges can be addressed by designing materials—chemical catalysts—that bind atomic hydrogen with medium strength and release molecular or gaseous hydrogen with very little heating. A random or systematic search for such catalysts, even with high-throughput techniques, would be very expensive and take many years. Scientists resorted to so-called density-functional theory, which is an electronic structure theory of matter, and other theories that describe chemical reactivity to design the ideal bimetallic catalysts, combinations of two metals, in special atomic arrangements that would result in solids with the desired properties. They arrived at a new theoretical construct called near-surface alloys of metals, such as a crystal of platinum containing a single layer of nickel atoms in its second row, that possesses the unique catalytic behavior sought. Having by now mapped entire families of such new theoretical materials—a feat unachievable by direct experimental means—these scientists have embarked on the challenge of fabricating these new structures and have already demonstrated their concept with a few successful examples.
- Devising the Next-Generation Wonder Molecules—Fine Chemistry inside Nano Cages. In the future drugs, fibers, fuel additives, molecular electronics devices, solar energy conversion dyes, and flavors may be synthesized in a similar manner using sets of discrete cavities to contain and isolate single molecules or just reacting pairs of molecules and catalysts. The "single-molecule catalysis" concept would allow maximum control of the environment surrounding a molecule, the spatial arrangement adopted by its atoms, the type of bonds made available for reaction, and even how the energy is coupled to and transferred to the molecule. Such level of control would result in the ability to break bonds or insert or remove atoms or change the spatial arrangement of atoms in very specific ways and not others. The resulting products would possess properties—chemical, biological, optical, electronic, or mechanical—superior to those achievable through less controllable chemistry. Researchers are beginning to show that this goal may be achievable. So-called supramolecular or larger-than-molecules cages made with organometallic compounds were used to host other organometallic complexes that have catalytic properties, such as the ability to specifically break carbon-hydrogen bonds. They have shown that certain carbon-hydrogen bonds are selectively broken and that only certain members of a chemical family undergo reaction, and not others. They have even shown that the constrained environment also leads to enhanced rate of production of the most desired product, which is in itself a revolutionary discovery.
- Controlling the Crash-landing of Biomolecules on Surfaces. Researchers have, for the first time, demonstrated that peptide ions retain at least one proton after soft landing on chemically modified, "fluffy" surfaces. Controlled deposition on surfaces holds great potential for applications such as selective chemical separations and analysis. Soft landing refers to the intact capture of large size-selected, charged molecules on surfaces of liquids or solids. Previous research suggests that soft landing provides a means for highly specific deposition of molecules of any size and complexity on surfaces using only a tiny fraction of material normally used in standard synthetic approaches. In the present studies, peptide ions are attractive as model systems that can provide important insights on the behavior of soft-landed macromolecules. The researchers used a specially designed mass

spectrometer configured for studying interactions of large ions with surfaces. The special characteristics of the instrument enabled quantitative investigation of the effect of the speed and mass of ions on the soft landing process. For example, it was determined that even collisions with high energies can result in deposition of intact ions on surfaces.

- Removal of Radium Ions from Water using Special "Grabber" Molecules. Researchers demonstrated a process that is highly selective for binding radium cations. It is a significant challenge to remove radioactive radium cations from wastewater since the large excess of other non-radioactive ions in solution can interfere with the selective extraction of radium. In the new work, a specially designed molecule was used to selectively bind radium. This supramolecular assembly made from isoguanosine is just the right size to extract radium in the presence of other cations such as magnesium and sodium.
- How Molecules Move through Small Holes. Measurements of transport through 15-nanometer pores have been compared to theoretical results to yield new understanding of differential transport at small scales. This knowledge is important for an understanding of separation processes at the molecular level, and could lead to a new generation of analytical devices based on microfluidic platforms. By adjusting physical parameters such as the channel diameter, and applying the appropriate external electrical potential, arrays of nanochannels—formed by nanocapillary array membranes—can be made to behave like digital fluidic switches, and the movement of molecules from one side of the array to the other side can be controlled. Combining model calculations with experimental characterization provides important insights into the mechanism of molecular transport and, additionally, provides quantitative measures of the surface characteristics of the interior of the pores.
- Using Thorium and Uranium to Activate the Carbon-Hydrogen and Carbon-Nitrogen Bonds in Molecules. The extent of electron-sharing in bonds with metals is an important property in catalysis. The correlation of bond covalency with reactivity can be elucidated by determining the reactivity of actinide (thorium, uranium, and other elements in the same row of the periodic table) ions with multiply bonded functional groups. Pyridine N-oxide (C_5H_5N-O), which has a relatively stable benzene-like ring, can transfer oxygen atoms to certain transition metals. Chemists have discovered that some uranium and thorium compounds can make C-H bonds in pyridine N-oxide more reactive by forming metal-carbon bonds. The structures of the products produced in these new reactions have been confirmed by x-ray crystallography. These reactions provide examples of C-H and C=N bond activation that is mediated by actinide metals. These studies may offer insights into catalytic removal of nitrogen-containing compounds from petroleum feedstocks, which is necessary to reduce nitrogen oxide emission in fuels.
- Elusive Carbon Dioxide Binding Mode Discovered in New Uranium Complex. Carbon dioxide (CO_2) is a stable molecule with two strong carbon-oxygen bonds. Inorganic chemists seek to mimic the catalytic chemical processes by which carbon dioxide is modified by plants to form sugars. This process can remove CO_2 from the atmosphere and minimize atmospheric release of CO_2 in industrial processes such as refinement of hydrocarbons. A new exquisitely-designed uranium complex has been found to react with CO_2 such that one electron is transferred from the U^{3+} center to CO_2, producing a species with an unusual linear CO_2 that binds to uranium and has one weaker oxygen-carbon bond. Uranium is an essential component of this species because the U^{3+} ion is large, electron-rich, and has the right structure to participate in bonding. This species is unique in that the CO_2 remains linear, with one C-O bond longer and weaker than the other. The molecular structure,

bond lengths and oxidation state were established experimentally. The linear M-O-C-O coordination had previously been seen only in an iron enzyme. The new uranium-CO_2 complex represents a chemical image of a catalytic process and may make it possible to design new catalysts to reduce the concentration of CO_2 in the atmosphere.

- Plutonium is Caged and Illuminated by Synchrotron Light. A new complexant, which was synthesized to extract plutonium and other actinide elements selectively, has shown promise to remove plutonium from mammals. Microscopic crystals (about the thickness of a human hair) of a plutonium complex have been produced to provide a structural model in order to design new actinide-selective binders. Using the Advanced Light Source, researchers determined the detailed structure of these crystals and showed that individual plutonium ions are trapped in cavities produced by eight oxygen atoms from the binder molecules. This structural determination will serve as a model of such complexes on which to base the design of novel molecules that are cages for toxic metals.
- Sheer Energy: Thinner, Cheaper Fuel Cell Catalysts. Fuel cells are a major source of clean energy in the hydrogen economy. Their economic development critically depends on cheaper electrocatalysts for oxygen reduction. The slow nature of this reaction causes a major limit in fuel cell efficiency. High precious metal content is another drawback of existing technology. Researchers coated five cheaper metals with a layer of platinum one atom thick and tested them. For most of the platinum "monolayers," the reaction occurred more slowly than it does on the thicker platinum layer currently used in fuel cells. But adding a monolayer of platinum to the cheaper metal palladium sped up the reaction. Theoretical computations predicted how the platinum monolayers are affected by atoms from the underlying layer of metal. The theory agreed well with the experiments and showed that a platinum monolayer on palladium balances two competing needs: it is reactive enough to break the bonds between oxygen atoms yet does not cling to the oxygen atoms so tightly that it prevents them from reacting with hydrogen. This method can dramatically decrease the expensive metal loading in fuel cells and improve cost and performance.
- Advances in Computational Chemistry Research. Basic research in computational chemistry has resulted in a superior method for the prediction of chemical behavior from computational quantum mechanics and statistical mechanics. The method is based on treating the solvent in which a molecule is placed as a continuum, and determining the cavity-formation energy from statistical mechanics, and the electric contributions from quantum mechanics. This work has now been published and a leading chemical process simulation company has incorporated this method into the most recent release of their industry dominating process simulator. This work will impact modern industrial plant and process design and lead to higher energy efficiencies through effective modeling of manufacturing processes.
- Is CO_2 Gone When You Put It In The Ground? There are only two options for dealing with increasing CO_2 concentrations in the atmosphere—get rid of new CO_2 actively or discontinue producing it and wait for natural processes to remove the excess over a very long time. Both approaches will likely be needed in the future. Researchers have been developing capabilities for realistic modeling of CO_2 injection into deep geological formations and for understanding dynamic processes associated with the injection in order to provide a scientific basis for evaluating the injections feasibility. Computational models were developed for coupling fluid properties, chemical and thermodynamic data, and rock-fluid interaction measurements. Reservoir dynamics were investigated on different levels of complexity and scale for natural and engineered systems. These

types of calculations also form the basis for understanding possible leaks which may be major regulatory and insurance concerns for large scale geological CO_2 sequestration. The improved computational codes from this project were also used as the basis for design calculations for CO_2 injection at the Frio Test Site as part of the Office of Fossil Energy funded Climate Change Technology Program.

- Improving Our Vision of the Subsurface. Large scale subsurface seismic measurements, although adequate for simple oil and gas exploration or waste site characterization, are inadequate for high hydrocarbon recovery rates or more effective environmental remediation or monitoring. Research is providing a better understanding of geophysical measurements of compressional and shear wave velocities, elastic moduli, and seismic anisotropy as they vary as functions of porosity, permeability, fluid contents, and stresses. A fiber-optic "optical" strainmeter has been developed that provides spatially averaged properties over a centimeter or "core" length scale intermediate between point measurements and a meter-scale bulk-measurements. The increased accuracy and sensitivity in measuring elastic deformation during applied sinusoidal stress will enable better discrimination between strain (elastic wave transmission efficiency) and phase lags (attenuation indicative of fluid content and type). In addition, the highly precise optical strain gage measurements will allow higher resolution testing of the significance of different types of heterogeneity at the core scale, in order to enable prediction of these properties at larger scales. The fiber optic sensor has been demonstrated to have a significantly higher sensitivity than other strain gages.
- The Auxin Receptor: A Holy Grail in Plant Science. The plant growth hormone called auxin is a small molecule, indole acetic acid (IAA)—too small to have the expected breadth of "informational" content to achieve its myriad effects of controlling the growth of leaves, stems, roots, flowers, fruits, and growth changes in response to light and gravity. Recent research demonstrated that IAA interacts directly with a much larger molecule, a protein, which was earlier shown to affect plant growth by stimulating the expression (activation) of certain growth-related genes. Now the solution to the mystery of auxin action is becoming clear. It turns out to be similar to an electric switch, but a bit more complex. We are beginning to unravel the molecular details of auxin's biological activity.

Detailed Program Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Chemical Sciences, Geosciences, and Energy Biosciences Research	**225,928**	**208,831**	**255,113**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**16,627**	**15,397**	**19,248**

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; the 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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

condensed phases. This has enhanced our ability to understand materials of all kinds and enables the full exploitation of the BES synchrotron light sources, electron beam micro-characterization centers, and neutron scattering facilities. Furthermore, by studying energy transfer within isolated molecules, AMO science provides the very foundation for understanding chemical reactivity, i.e., the process of energy transfer between molecules and ultimately the making and breaking of chemical bonds. The AMO Science activity is the sole supporter of synchrotron-based AMO science studies in the U.S., which includes ultrashort x-ray pulse generation and utilization at the ALS and APS. This program is also the principal U.S. supporter of research in the properties and interactions of highly charged atomic ions, which are of direct consequence to fusion plasmas.

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 2007, 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; 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 coherent control of quantum systems ($+851,000), ultrafast science ($+2,000,000), chemical imaging ($+500,000), and mid-scale instrumentation ($+500,000).

	FY 2005	FY 2006	FY 2007
▪ **Chemical Physics Research**	**32,946**	**31,866**	**37,813**

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.

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 significantly 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

	FY 2005	FY 2006	FY 2007

(dollars in thousands)

will be used in models for the design of new combustion devices with maximum energy efficiency and minimum undesired environmental consequences.

The research in chemical dynamics at surfaces is aimed at developing predictive theories for surface mediated chemistry such as is encountered in industrial catalysis or environmental processes. Surface mediated catalysis reduces the energy demands of industrial chemical processes by bypassing energy barriers to chemical reaction. Surface mediated catalysis is used to remove pollutants from combustion emissions.

The SciDAC computational chemistry program addresses two fundamental research efforts: (1) chemically reacting flows and (2) the chemistry of unstable species and large molecules. Each of these research efforts is carried out by a team of related scientists working with the appropriate Integrated Software Infrastructure Centers supported under SciDAC by the SC Advanced Scientific Computing Research program.

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

In FY 2007, 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 condensed phase and interfacial molecular science ($+1,000,000), ultrafast science ($+1,000,000), chemical imaging ($+750,000), mid-scale instrumentation ($+500,000), emergent behavior ($+1,000,000), and solar energy conversion ($+1,697,000).

▪ **Photochemistry and Radiation Research**................................	**30,446**	**25,489**	**32,007**

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, 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

charge separation in molecule-based biomimetic assemblies should also be applicable in the future development of molecular optoelectronic devices. A strong interface with the Office of Energy Efficiency and Renewable Energy (EE) solar conversion programs exists at National Renewable Energy Laboratory (NREL), involving shared research, analytical and fabrication facilities, and involving a jointly shared project on dye-sensitized solar cells.

Radiation chemistry research supports fundamental chemical effects produced by the absorption of energy from ionizing radiation. This research is important for solving problems in environmental waste management and remediation, nuclear energy production, and medical diagnosis and radiation therapy.

This activity is the dominant supporter (85%) of solar photochemistry in the U.S., and the sole supporter of radiation chemistry.

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 2007, 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 ultrafast science ($+1,000,000), solar energy conversion ($+3,909,000), and research related to the hydrogen economy ($+1,609,000).

	FY 2005	FY 2006	FY 2007
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	**13,640**	**12,411**	**18,188**

This activity supports fundamental research at the interface between the biological and physical sciences to characterize the molecular and chemical mechanisms involved in the conversion of solar energy to stored chemical energy. Research supported includes the characterization of the chemical processes occurring during photosynthesis, the kinetic and catalytic mechanisms of enzymes involved in the synthesis chemical fuels, and the biochemical mechanisms involved in the fixation of carbon dioxide. The approaches used include biophysical, biochemical, and molecular structure/function analyses. The goal is to enable the future biotechnological exploitation of both natural and synthetic systems and to provide insights and strategies into the design of non-biological and hybrid processes. This activity encourages fundamental research that employs novel approaches that integrate biological sciences with physical sciences in order to understand the molecular details of energy conversion by natural systems.

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

In FY 2007, 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.

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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 for biophysical characterization of biomolecular complexes ($+500,000), chemical imaging ($+750,000), emergent behavior ($+500,000) solar energy conversion ($+3,909,000), and research related to the hydrogen economy ($+118,000).

	FY 2005	FY 2006	FY 2007
▪ **Metabolic Regulation of Energy Production**	**19,427**	**17,554**	**17,601**

This activity supports fundamental research in the molecular processes that constitute and regulate metabolic pathways that are involved in cellular chemical conversions of importance to energy. Understanding the molecular mechanisms of chemical transformations and the control of chemical transformation pathways in living systems, such as plants, provides the basis for modifying biological processes and designing bioinspired, synthetic systems for applications in energy technologies. The research goal is to develop a predictive and experimental context for the manipulation of metabolism to accumulate a desired product and to design and synthesize robust bioinspired and biomimetic systems, including hybrid systems that achieve desired chemical transformations with high efficiency and specificity. Research supported includes the molecular characterization of metabolic pathways and the signaling pathways that enhance or limit their activity in living systems, and structure/function studies of key biomolecular components, signal transducers, molecular machines, 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 chemical catalysis in living systems and provides the basis for manipulation of biological chemistry and the development of bioinspired and biomimetic systems for specific chemical transformations.

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

In FY 2007, increased emphasis will be placed upon understanding interactions that occur within the nanoscale range; this includes signal reception at biological surfaces and membranes, enzyme-substrate recognition, and the structure/function of molecular complexes and molecular machines that enable and control chemical transformations. An emerging area will be the development of new imaging tools and methods to examine metabolic and signaling pathways at both the physical-spatial and temporal scale. Within this funding, there is an increase for research related to the hydrogen economy ($+47,000).

	FY 2005	FY 2006	FY 2007
▪ **Catalysis and Chemical Transformation**	**37,871**	**38,107**	**47,459**

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 which 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.

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 2007, 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 ultrafast science ($+1,000,000), chemical imaging ($+750,000), mid-scale instrumentation ($+500,000), solar energy conversion ($+3,659,000), and research related to the hydrogen economy ($+3,443,000).

▪ **Separations and Analyses**	**15,490**	**17,287**	**24,041**

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.

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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 2007, 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) will allow multiple analytical measurements to be 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 molecular science for advanced chemical separations ($+1,000,000), chemical imaging ($+1,750,000), mid-scale instrumentation ($+500,000), emergent behavior ($+1,000,000), research related to the hydrogen economy ($+808,000), and solar energy conversion ($+1,696,000).

	FY 2005	FY 2006	FY 2007
▪ **Heavy Element Chemistry**	**10,506**	**9,354**	**17,128**

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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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 products 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 in order 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 2007, 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 advanced fuel cycles for future nuclear energy needs. 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 mid-scale instrumentation ($+500,000) and research related to advanced fuel cycles ($+7,274,000).

▪ **Geosciences Research**	**22,212**	**20,494**	**22,345**

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.

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.

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

In FY 2007, funding will continue to provide the majority of individual investigator basic research funding 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 quality portfolios. Within this funding, there are increases for nanoscale geochemistry ($+851,000), chemical imaging ($+500,000) and mid-scale instrumentation ($+500,000).

	FY 2005	FY 2006	FY 2007
▪ **Chemical Energy and Chemical Engineering**	**11,938**	**3,731**	**1,817**

This activity supports research on electrochemistry, thermophysical and thermochemical properties, and physical and chemical rate processes. Also included is fundamental research in areas critical to understanding the underlying limitations in the performance of electrochemical energy storage and conversion systems including anode, cathode, and electrolyte systems and their interactions with emphasis on improvements in performance and lifetime. The program covers a broad spectrum of research including fundamental studies of composite electrode structures; failure and degradation of active electrode materials; thin film electrodes, electrolytes, and interfaces; and experimental and theoretical aspects of phase equilibria, especially of mixtures, including supercritical phenomena.

Capital equipment is provided for such items as computer work stations and electrochemical apparatus.

In FY 2007, in order to emphasize other priorities, there will be reductions in research in the areas of physical properties related to process engineering, engineering approaches to electrochemical fuel cells, and aspects of advanced battery research.

	FY 2005	FY 2006	FY 2007
▪ **General Plant Projects (GPP)**	**9,832**	**13,124**	**13,408**

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 Biosciences subprogram. The total estimated cost of each GPP project will not exceed $5,000,000.

	FY 2005	FY 2006	FY 2007
▪ **General Purpose Equipment (GPE)**..	**4,993**	**4,017**	**4,058**

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 2005	FY 2006	FY 2007
	(dollars in thousands)		
Facility Operations	**6,437**	**6,251**	**6,805**

The facility operations budget request, which includes operating funds, capital equipment, and GPP, 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 2005	FY 2006	FY 2007
Combustion Research Facility	6,437	6,251	6,805
SBIR/STTR	**—**	**5,468**	**6,581**

In FY 2005 $5,213,000 and $626,000 were transferred to the SBIR and STTR programs, respectively. The FY 2006 and FY 2007 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

	FY 2005	FY 2006	FY 2007
Total, Chemical Sciences, Geosciences, and Energy Biosciences	**232,365**	**220,550**	**268,499**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Chemical Sciences, Geosciences, and Energy Biosciences Research	
▪ **Atomic, Molecular, and Optical (AMO) Science**	
Increases are provided for coherent control of quantum systems ($+851,000), ultrafast science ($+2,000,000), chemical imaging ($+500,000), and mid-scale instrumentation ($+500,000)	+3,851
▪ **Chemical Physics Research**	
Increases are provided for condensed phase and interfacial molecular science ($+1,000,000), ultrafast science ($+1,000,000), chemical imaging ($+750,000), mid-scale instrumentation ($+500,000), emergent behavior ($+1,000,000), and solar energy conversion ($+1,697,000).	+5,947
▪ **Photochemistry and Radiation Research**	
Increases are provided for research related to the hydrogen economy ($+1,609,000), ultrafast science ($+1,000,000), and solar energy conversion ($+3,909,000)	+6,518

	FY 2007 vs. FY 2006 ($000)
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	
Increases are provided for biophysical characterization of biomolecular complexes ($+500,000), research related to the hydrogen economy ($+118,000), chemical imaging ($+750,000), emergent behavior ($+500,000), and solar energy conversion ($+3,909,000).	+5,777
▪ **Metabolic Regulation of Energy Production**	
Increase is provided for research related to the hydrogen economy	+47
▪ **Catalysis and Chemical Transformation**	
Increases are provided for research related to the hydrogen economy ($+3,443,000), ultrafast science ($+1,000,000), chemical imaging ($+750,000), mid-scale instrumentation ($+500,000), and solar energy conversion ($+3,659,000)	+9,352
▪ **Separations and Analyses**	
Increases are provided for molecular science for advanced chemical separation ($+1,000,000), research related to the hydrogen economy ($+808,000), chemical imaging ($+1,750,000), mid-scale instrumentation ($+500,000), emergent behavior ($+1,000,000), and solar energy conversion ($+1,696,000).	+6,754
▪ **Heavy Element Chemistry**	
Increases are provided for mid-scale instrumentation ($+500,000) and research relevant to advanced fuel cycles ($+7,274,000)	+7,774
▪ **Geosciences Research**	
Increases are provided for nanoscale geochemistry ($+851,000), chemical imaging ($+500,000), and mid-scale instrumentation ($+500,000)	+1,851
▪ **Chemical Energy and Chemical Engineering**	
Reductions in research in the areas of physical properties related to process engineering, engineering approaches to electrochemical fuel cells, and aspects of advanced battery research	-1,914
▪ **General Plant Projects (GPP)**	
Increase in general plant projects intended to help alleviate recurring maintenance costs by improving infrastructure.	+284
▪ **General Purpose Equipment (GPE)**	
Small increase for GPE maintenance of equipment	+41
Total, Chemical Sciences, Geosciences and Energy Biosciences Research	**+46,282**

	FY 2007 vs. FY 2006 ($000)
Facility Operations	
Increase for the Combustion Research Facility to support operations	+554
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in operating expenses.	+1,113
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences	**+47,949**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Construction			
Spallation Neutron Source (ORNL)	79,891	41,327	—
Project Engineering Design, Nanoscale Science Research Centers	1,996	—	—
Project Engineering Design, Linac Coherent Light Source (SLAC)	19,914	2,518	161
Linac Coherent Light Source (SLAC)	29,760	82,170	105,740
Center for Functional Nanomaterials (BNL)	18,317	36,187	18,864
The Molecular Foundry (LBNL)	31,828	9,510	257
Center for Nanophase Materials Science (ORNL)	17,669	—	—
Center for Integrated Nanotechnologies (SNL/LANL)	30,650	4,580	247
Project Engineering Design, National Synchrotron Light Source-II (BNL)	—	—	20,000
Project Engineering Design, Advanced Light Source User Support Building (LBNL)	—	—	3,000
Total, Construction	230,025	176,292	148,269

Description

Construction is needed to support the research in each of the subprograms in the BES program. Experiments necessary in support of basic research require that state-of-the-art facilities be built or existing facilities modified to meet unique research requirements. Reactors, x-ray light sources, and neutron sources are among the expensive, but necessary, facilities required. The budget for the BES program includes funding for the construction and modification of these facilities.

Benefits

The new facilities that are under construction—the Linac Coherent Light Source, the Center for Functional Nanomaterials, design of 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 in order 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 2005	FY 2006	FY 2007
▪ **Spallation Neutron Source (SNS), ORNL**	**79,891**	**41,327**	**—**

The purpose of the SNS Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering. The SNS will be used by researchers from academia, national and federal labs, and industry for basic and applied research and for technology development in the fields of condensed matter physics, materials sciences, magnetic materials, polymers and complex fluids, chemistry, biology, earth sciences, and engineering. When commissioning is complete, the SNS will be significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence. The facility will be used by 1,000–2,000 scientists and engineers annually. Interest in the scientific community in the SNS is increasing.

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 will initially be one partially instrumented target station with the potential for adding more instruments and a second target station later.

The SNS project partnership among six DOE laboratories 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.

In FY 2001, two grants were awarded to universities for research requiring the design, fabrication, and installation of instruments for neutron scattering. These instruments will be sited at the SNS, with commissioning beginning late in FY 2006, shortly after the SNS facility itself is commissioned. Both awards were made based on competitive peer review conducted under 10 CFR Part 605, Financial Assistance Program.

Funds appropriated in FY 2002 continued R&D, design, procurement, construction activities, and component installation. Essentially all R&D supporting construction of the SNS was completed, with instrument R&D continuing. Title II design was completed on the linac and was continued on the ring, target, and instrument systems. The completed ion source and portions of the drift tube linac were delivered to the site and their installation was begun. Other system components for the accelerator, ring, target, and instruments continued to be manufactured. Work on conventional facilities continued, with some reaching completion and being turned over for equipment installation, such as the ion source building and portions of the klystron building and linac tunnel. Construction work began on the ring tunnel.

Funds appropriated in FY 2003 continued instrument R&D and design, procurement, construction, installation, and commissioning. The ion source was commissioned; the drift tube linac was installed and commissioning was begun; installation of other linac components progressed; and installation of ring components began. Target building construction and equipment installation continued.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

Numerous conventional facilities, including the klystron, central utilities, and ring service buildings and the linac and ring tunnels, were advanced. Site utilities became available to support linac commissioning. In FY 2003, a Major Item of Equipment (MIE) was initiated for five SNS instruments: High-Pressure Diffractometer, High-Resolution Chopper Spectrometer, Single-Crystal Diffractometer, Disordered Materials Diffractometer, and Hybrid Polarized Beam Spectrometer. The MIE is funded at $3,143,000 in FY 2005, $12,579,000 in FY 2006, and $10,500,000 in FY 2007. These instruments will be built by individual DOE laboratories or consortia of DOE laboratories in collaboration with the SNS based on scientific merit and importance to users from universities, industries, and government laboratories. A second Major Item of Equipment is initiated in FY 2007 for an additional four to five instruments.

Funds appropriated in 2004 continued instrument R&D, design, and procurement. The drift-tube linac and cavity-coupled linac portions of the warm linac commissioning were completed. Other commissioning activities continued in the linac. Cryogenic refrigerator installation and system cool down were advanced. High-energy beam transport installation and testing were completed. Ring fabrication and assembly activities continued. Target fabrication and assembly activities continued. Most SNS buildings are completed with the exception of ongoing construction work in the target and instrument facilities and the central laboratory and office building.

Funds appropriated in FY 2005 continued R&D, procurement, and installation of equipment for instrument systems. Commissioning of Linac Systems was completed. Commissioning of the high-energy beam transport and accumulator ring was begun; installation and testing for the ring-target beam transport system was performed. Installation and testing was performed and preparation for the readiness review was started for target systems. The remaining major construction contracts were completed. Procurement, installation, and testing continued for integrated control systems.

Funds appropriated in FY 2006 will complete the SNS Project. Procurement and installation of equipment for instrument systems will be performed. An accelerator readiness review will be completed and target systems will be commissioned. All requirements to begin operations will be met and all SNS facilities will be turned over to operations. The estimated Total Project Cost is $1,411,282,560, and the construction schedule continues to call for project completion by mid-2006.

▪ **Project Engineering and Design, Nanoscale Science Research Centers**	**1,996**	**—**	**—**

Project Engineering and Design funds provide Title I and Title II design-only funding for Nanoscale Science Research Centers (NSRCs) at Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, Sandia National Laboratories (Albuquerque), and Brookhaven National Laboratory. These funds were used to assure project feasibility, define the scope, and provide estimates of construction costs and schedules. NSRCs provide state-of-the-art facilities for materials nanofabrication and advanced tools for nanocharacterization to the scientific community.

▪ **Project Engineering and Design, Linac Coherent Light Source, SLAC**	**19,914**	**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 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 nanosctructured materials, at atomic or near-atomic resolution. These are only a few examples of breakthrough science that will be enabled by LCLS, planned to be the world's first "fourth generation" x-ray light source.

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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

Funds were appropriated in FY 2006 and are requested in FY 2007 for Project Engineering Design (PED) Title I and Title II design work. Additional information on the LCLS Project is provided in the LCLS PED data sheet, project number 03-SC-002.

▪ **Linac Coherent Light Source, SLAC**	**29,760**	**82,170**	**105,740**

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 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 will support physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Central Laboratory and Office Building. In addition, the injector will be completed and construction of the downstream linac and electron beam transport to the undulator hall will begin. Undulator module assembly will be started along with construction of x-ray transport/optics/diagnostics systems.

FY 2007 budget authority is requested to continue physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Central Laboratory and Office (CLO) building.

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

▪ **Nanoscale Science Research Center – The Center for Functional Nanomaterials, BNL**..	**18,317**	**36,187**	**18,864**

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 funding is requested to 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 data sheet. Additional information is provided in the construction project data sheet 05-R-321.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Nanoscale Science Research Center – The Molecular Foundry, LBNL**	**31,828**	**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 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 data sheet. Additional information is provided in the construction project data sheet 04-R-313.

▪ **Nanoscale Science Research Center – The Center for Nanophase Materials Sciences, ORNL**	**17,669**	**—**	**—**

The Center for Nanophase Materials Sciences (CNMS), a BES Nanoscale Science Research Center, will include a research center and user facility that will integrate nanoscale science research with neutron science, synthesis science, and theory/modeling/simulation. A new building will provide state-of-the-art clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. Included will be equipment to synthesize, manipulate, and characterize nanoscale materials and structures. The Center, collocated at the Spallation Neutron Source complex, will have as its major scientific thrusts nano-dimensioned soft materials, complex nanophase materials systems, and the crosscutting areas of interfaces and reduced dimensionality that become scientifically critical on the nanoscale. A major focus of the CNMS will be to exploit ORNL's unique facilities and capabilities in neutron scattering.

FY 2004 and FY 2005 funding was requested for the construction of the Center for Nanophase Materials Science located at Oak Ridge National Laboratory. Performance was measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet.

▪ **Nanoscale Science Research Center – The Center for Integrated Nanotechnologies, SNL/LANL**	**30,650**	**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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

nanoscale materials and structures. CINT focus areas are nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and the nanoscale/bio/microscale interfaces. CINT will be jointly administered by Los Alamos National Laboratory and Sandia National 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 data sheet. Additional information is provided in the construction project data sheet 03-R-313.

	FY 2005	FY 2006	FY 2007
▪ **Project Engineering and Design, National Synchrotron Light Source-II (NSLS-II), BNL**...	**—**	**—**	**20,000**

The NSLS-II would be a new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will 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 will be the best storage-ring-based synchrotron light source in the world, but, more importantly, NSLS-II will be transformational in that it will open new regimes of scientific discovery and investigation.

FY 2007 funding is requested to begin Project Engineering and Design (PED) Title I and Title II design. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information is provided in the construction project data sheet 07-SC-06.

	FY 2005	FY 2006	FY 2007
▪ **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 is requested to begin Project Engineering and Design. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information is provided in the construction project data sheet 07-SC-12.

	FY 2005	FY 2006	FY 2007
Total, Construction...	**230,025**	**176,292**	**148,269**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
▪ **Spallation Neutron Source, ORNL**	
Decrease in funding for construction of the Spallation Neutron Source at ORNL, representing the scheduled completion of the project.	-41,327
▪ **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 the scheduled decrease in activities.	-2,357
▪ **Linac Coherent Light Source, SLAC**	
Increase in funding to continue construction for the LCLS project.	+23,570
▪ **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.	-17,323
▪ **Nanoscale Science Research Center – The Molecular Foundry, LBNL**	
Decrease in funding for construction of the Molecular Foundry at LBNL, representing the scheduled ramp down of activities.	-9,253
▪ **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 scheduled ramp down of activities.	-4,333
▪ **Project Engineering and Design, National Synchrotron Light Source-II (NSLS II), BNL**	
Increase in funding to initiate Project Engineering and Design	+20,000
▪ **Project Engineering and Design, Advanced Light Source (ALS) User Support Building, LBNL**	
Increase in funding to initiate Project Engineering and Design	+3,000
Total Funding Change, Construction	**-28,023**

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 2005	FY 2006	FY 2007
Major User Facilities			
Advanced Light Source at Lawrence Berkeley National Laboratory.	44,800	42,783	49,802
Advanced Photon Source at Argonne National Laboratory	100,500	95,890	108,604
National Synchrotron Light Source at Brookhaven National Laboratory	36,750	36,196	40,763
Center for Nanophase Materials Sciences at Oak Ridge National Laboratory	—	17,800	19,190
Center for Integrated Nanotechnologies at Sandia National Laboratories/Albuquerque and Los Alamos National Laboratory	—	11,900	19,190
Molecular Foundry at Lawrence Berkeley National Laboratory	—	8,100	19,190
Center for Nanoscale Materials at Argonne National Laboratory	—	3,500	19,190
Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center.	32,388	25,475	35,836
High Flux Isotope Reactor at Oak Ridge National Laboratory.	46,900	43,330	51,598
Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory.	4,500	—	—
Intense Pulsed Neutron Source at Argonne National Laboratory.	16,800	15,500	18,531
Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory.	9,588	10,000	10,582
Spallation Neutron Source at Oak Ridge National Laboratory.	37,600	101,001	171,409
Combustion Research Facility at Sandia National Laboratories/California.	6,437	6,251	6,805
National Synchrotron Light Source-II at Brookhaven National Laboratory	1,000	—	25,000
Linac Coherent Light Source (LCLS) at Stanford Linear Accelerator Center	—	3,500	16,000
Linac for LCLS	—	29,700	40,000
Total, Major User Facilities	337,263	450,926	651,690

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

	FY 2005	FY 2006	FY 2007
	(dollars in thousands)		
General Plant Projects	16,532	13,695	15,624
Accelerator Improvement Projects	10,245	8,032	25,112
Capital Equipment	86,639	69,123	131,657
Total, Capital Operating Expenses	113,416	90,850	172,393

Construction Projects

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Unappro-priated Balances
	(dollars in thousands)					
07-SC-06, PED, BNL, National Synchrotron Light Source-II	75,000	—	—	—	20,000	55,000
07-SC-12, PED, LBNL, Advanced Light Source User Support Building	3,000	—	—	—	3,000	—
05-R-320, SLAC, Linac Coherent Light Source	315,000[a]	—	29,760	82,170	105,740	61,356
05-R-321, BNL, Center for Functional Nanomaterials	79,700[b]	—	18,317	36,187	18,864	366
04-R-313, LBNL, The Molecular Foundry	83,604[c]	34,794	31,828	9,510	257	—
03-SC-002, PED, SLAC, Linac Coherent Light Source	35,974	13,381	19,914	2,518	161	—
03-R-312, ORNL, Center for Nanophase Materials Sciences	63,740[d]	43,583	17,669	—	—	—
03-R-313, SNL, Center for Integrated Nanotechnologies	73,754[e]	34,118	30,650	4,580	247	—
02-SC-002 PED, Nanoscale Science Research Centers	19,828	17,832	1,996	—	—	—
99-E-334, ORNL, Spallation Neutron Source	1,192,283	1,071,065	79,891	41,327	—	—
Total, Construction			230,025	176,292	148,269	

[a] Includes $35,974,000 of PED included in the 03-SC-002 PED, SLAC, Linac Coherent Light Source datasheet.
[b] Includes $5,966,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[c] Includes $7,215,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[d] Includes $2,488,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[e] Includes $4,159,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Completion Date
ANL, Center for Nanoscale Materials.......	72,500[a]	36,000	10,000	12,000	14,000	—	FY 2006
ORNL, Spallation Neutron Source Instrumentation I[b]	68,500	68,500	13,022	3,143	12,579	10,500	FY 2007–FY 2011 est.
LBNL, Transmission Electron Aberration Corrected Microscope....	25,000–30,000	11,200–13,500	—	—	2,000	3,500	TBD
ORNL, Spallation Neutron Source Instrumentation II	40,000–60,000	40,000–60,000	—	—	—	10,000	TBD
SLAC, Linac Coherent Light Source Instumentation	50,000–60,000	50,000–60,000	—	—	—	10,000	TBD
Total, Major Items of Equipment			23,022	15,143	28,579	34,000	

[a] This includes $36,000,000 provided by the State of Illinois for construction of the building.
[b] 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.

07-SC-06, Project Engineering and Design (PED), National Synchrotron Light Source II, Brookhaven National Laboratory

1. Significant Changes

This is the initial project engineering and design datasheet for this project.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2007	2Q FY 2007	4Q FY 2008	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	75,000	46,000	N/A	121,000	N/A	121,000

4. Project Description, Justification, and Scope

The National Synchrotron Light Source II (NSLS-II) would be a new synchrotron light source, highly optimized to deliver ultra-high brightness and flux and exceptional beam stability. It will also provide advanced insertion devices, optics, detectors, robotics, and an initial suite of scientific instruments. Together, these will enable the study of material properties and functions with a spatial resolution of ~1 nm, an energy resolution of ~0.1 meV, and the ultra-high sensitivity required to perform spectroscopy on a single atom.

Major advances in energy technologies will require scientific breakthroughs in developing new materials with advanced properties. A broad discussion is given in several recent reports, including the Basic Energy Sciences Advisory Committee Reports *Opportunities for Catalysis in the 21st Century* and *Basic Research Needs to Assure a Secure Energy Future*, the Basic Energy Sciences (BES) reports *Basic Research Needs for the Hydrogen Economy* and *Basic Research Needs for Solar Energy Utilization*, the Report of the Nanoscale Science, Engineering, and Technology Subcommittee of the National Science and Technology Committee *Nanoscience Research for Energy Needs*, and the Nuclear Energy Research Advisory Committee Report *A Technology Roadmap for Generation IV Nuclear Energy Systems*.

Collectively, these reports underscore the need to develop new tools that will allow the characterization of the atomic and electronic structure, the chemical composition, and the magnetic properties of materials *with nanoscale resolution*. Needed are non-destructive tools to image and characterize buried structures and interfaces, and these tools must operate in a wide range of temperature and harsh

[a] The estimates in section 3 are for PED only. The full project TPC (design and construction) range approved at Critical Decision-0, Approve Mission Need, excluding offsetting D&D, is $600,000,000 to $800,000,000. This estimate is preliminary and should not be construed to be validated project baseline.

environments. The absence of any tool possessing these combined capabilities was identified as a key barrier to progress in the 1999 BES Report *Nanoscale Science, Engineering and Technology Research Directions*.

In order to fill this capability gap and to further the accomplishment of its mission, the BES program will need a synchrotron light source that will 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 will provide these capabilities. Only x-ray methods have the potential of satisfying all of these requirements, but advances both in x-ray optics and in x-ray brightness and flux are required to achieve a spatial resolution of 1 nm and an energy resolution of 0.1 meV.

There are no alternative tools with a spatial resolution of 1 nm and energy resolution of 0.1 meV that also have the required capabilities of being non-destructive and able to image and characterize buried structures and interfaces in a wide range of temperatures and harsh environments. An analysis found that upgrading existing light sources was either impossible or not very cost effective. In the case of NSLS-I, it was found that it would be impossible to upgrade this light source due to numerous technical difficulties, including accelerator physics and infrastructure constraints, such as its small circumference, which limit the feasible in-place upgrade options.

Research and Development activities funded under Other Project Costs will address technical risk in four key areas: energy resolution, spatial resolution, superconducting undulators, and superconducting storage ring magnets.

The NSLS-II project will design, build, and install the accelerator hardware, experimental apparatus, civil construction, and central facilities required to produce a new synchrotron light source. It includes a third generation storage ring, full energy injector, experimental areas, and appropriate support equipment, all housed in a new building.

The Project Engineering and Design (PED) funds requested for NSLS-II will allow the project to proceed from conceptual design into preliminary and detailed design. These funds will assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, develop working drawings and specifications, and provide schedules for construction and procurements. Should a decision to proceed with construction be reached, this design effort will ensure that construction could begin on schedule in FY 2009.

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs presented in this datasheet are preliminary estimates for project engineering and design only. The preliminary schedule for project Critical Decisions is as follows:

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—4Q FY 2005
- Critical Decision-1: Approve Preliminary Baseline Range—2Q FY 2007
- Performance Baseline External Independent Review Final Report—1Q FY 2008
- Critical Decision-2: Approve Performance Baseline—1Q FY 2008

- Critical Decision-3: Approve Start of Construction—4Q FY 2008
- Critical Decision-4: Approve Start of Operations—FY 2013

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2007	20,000	20,000	19,000
2008	55,000	55,000	56,000
Total, Design PED	75,000	75,000	75,000

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design	75,000	N/A

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning	1,000	N/A
R&D	45,000	N/A
Total, OPC	46,000	N/A

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC(Design)	—	14,000	61,000	—	—	—	—	75,000
OPC (Design)	1,000	25,000	20,000	—	—	—	—	46,000
Total, Project Costs (Design)	1,000	39,000	81,000	—	—	—	—	121,000

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach (formerly Method of Performance)

A formal acquisition strategy will be prepared prior to CD-1 estimated for 1Q FY 2007.

07-SC-12, Project Engineering and Design (PED), Advanced Light Source User Support Building, Lawrence Berkeley National Laboratory

1. Significant Changes

This is the initial project engineering and design datasheet for this project.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2007.......	1Q FY 2007	2Q FY 2008	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	3,000	400	N/A	3,400	N/A	3,400

4. Project Description, Justification, and Scope

At Lawrence Berkeley National Laboratory (LBNL), there is a critical shortage of high quality user support space. Users are presently accommodated in Building 10 and adjacent spaces that are ill-suited for their current use, and in the case of Building 10, structurally deficient. This shortage of suitable space for users creates significant impediments to the attainment of mission objectives. The User Support Building will support the major BES user facilities at LBNL, primarily the Advanced Light Source (ALS), the Office of Science's only third generation UV and soft x-ray synchrotron radiation source. The new building will also allow construction of an ultra-high resolution ALS beamline in an energy range suitable for use by multiple physical science and life science users. The unique science being performed at the ALS, cannot be supported by facilities at any other location. In particular, assembly of experimental equipment for use at the ALS needs to be performed in high-quality space located adjacent to the facility. The project is consistent with LBNL's Strategic Facilities Plan.

This project will provide a new facility of approximately 30,000 gross square foot (gsf) that includes a high bay for assembly of experimental equipment, precision component assembly areas, wet laboratories, and office space. It will be designed to support over 2,000 scientific facility users annually that are expected due to the growth of user programs at LBNL. The User Support Building project scope will also include road improvements to provide better access to the new User Support Building facility. Sustainable building principles will be incorporated into the design and construction.

The Project Engineering and Design (PED) funds requested in FY 2007 for the User Support Building will allow the project to proceed from conceptual design into preliminary and detailed design. These funds will be used to further define the scope, provide detailed estimates of construction costs based on

[a] The estimates in section 3 are for PED only. The full project TEC (design and construction) is estimated to be in the range of $30,000,000 to $35,000,000. This estimate is preliminary and should not be construed to be a validated project baseline.

the approved design, develop working drawings and specifications, and provide schedules for construction and procurements. The design effort will ensure that construction can start in FY 2008.

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs represented in this datasheet are preliminary estimates for project engineering and design only. The preliminary schedule for project Critical Decisions is as follows:

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2003
- Critical Decision-1: Approve Preliminary Baseline Range—3Q FY 2006
- External Independent Review Final Report—1Q FY 2007
- Critical Decision-2: Approve Performance Baseline—1Q FY 2007
- Critical Decision-3: Approve Start of Construction—4Q FY 2007
- Critical Decision-4: Approve Start of Operations—FY 2010

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2007	3,000	3,000	2,700
2008	—	—	300
Total, Design PED	3,000	3,000	3,000

6. Details of Project Cost Estimate

Total Estimated Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Preliminary and Final Design	3,000	N/A

Other Project Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Conceptual Planning	400	N/A

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC(Design).....................	—	2,700	300	—	—	—	—	3,000
OPC (Design)....................	400	—	—	—	—	—	—	400
Total, Project Costs (Design)	400	2,700	300	—	—	—	—	3,400

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

A formal acquisition strategy will be prepared prior to CD-1 (estimated for 3Q FY 2006).

05-R-320, Linac Coherent Light Source, Stanford Linear Accelerator Center, Menlo Park, California

1. Significant Changes

There have been no significant changes to scope, cost, or schedule.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design Start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006	2Q FY 2003	4Q FY 2006	3Q FY 2006	2Q FY 2009	N/A	N/A
FY 2007	2Q FY 2003	4Q FY 2006	3Q FY 2006	2Q FY 2009	N/A	N/A

3. Baseline and Validation Status

(dollars in thousands)

	TEC[a]	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs[a]	Validated Performance Baseline	Preliminary Estimate
FY 2006	315,000	64,000	—	379,000	379,000	N/A
FY 2007	315,000	64,000	—	379,000	379,000	N/A

4. Project Description, Justification, and Scope

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 brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray Free Electron Laser (FEL) in the 1.5–15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems described below. This will be the world's first such facility.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 GeV for colliding beam experiments and for nuclear and high-energy physics experiments on fixed targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into PEP-II, and the entire linac is used for fixed target experiments. When the LCLS is completed, the latter activity will be limited to 25 percent of the available beam time and the last one-third of the linac will be available for the LCLS a minimum of 75 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5–15 GeV electron bunches at a 120 Hertz repetition rate. When traveling through the new 120 meter long LCLS undulator, these electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent x-ray beam for scientific research.

[a] The full project TEC and TPC, established at Critical Decision 2b (Approve Performance Baseline), are $315,000,000 and $379,000,000, respectively, and include the costs for PED from project 03-SC-002.

The LCLS makes use of technologies developed for SLAC and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radiofrequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of x-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current x-ray sources (both synchrotron radiation light sources and so-called "table-top" x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser-like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing 10^{11} x-ray photons in a pulse with duration of less than 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific application in the chemical, material, and biological sciences.

The LCLS Project requires a 135 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 undulator and associated equipment. Two new buildings, the Near Experimental Hall and the Far Experimental Hall, will be constructed and connected by the beam line tunnel. A Central Laboratory and Office Building will be constructed to provide laboratory and office space for LCLS users and serve as a center of excellence for basic research in x-ray physics and ultrafast science.

The combined characteristics (spectral content, peak power, pulse duration, and coherence) of the LCLS beam are far beyond those of existing light sources. The demands placed on the x-ray instrumentation and optics required for scientific experiments with the LCLS are unprecedented. The LCLS experimental program will commence with: measurements of the x-ray beam characteristics and tests of the capabilities of x-ray optics; instrumentation; and techniques required for full exploitation of the scientific potential of the facility. For this reason, the project scope includes a comprehensive suite of instrumentation for characterization of the x-ray beam and for early experiments in atomic, molecular, and optical physics. The experiments include x-ray multiphoton processes with isolated atoms, simple molecules, and clusters. Also included in the scope of the LCLS Project are the instrumentation and infrastructure necessary to support research at the LCLS, such as experiment hutches and associated interlock systems; computers for data collection and data analysis; devices for attenuation and collimation of the x-ray beam; prototype optics for manipulation of the intense x-ray beam; and synchronized pump lasers.

Beyond the scope of the LCLS construction project, an instrument development program has been implemented in order to qualify and provide instruments for the LCLS. The key element of this program is a Major Item of Equipment—the LCLS Ultrafast Science Instruments (LUSI) project. Instrument proposals will undergo a scientific peer review process to evaluate technical merit; those concepts that are accepted may then establish interface agreements with the LCLS Project. Expected funding sources include appropriated funds through the Department of Energy and other Federal agencies, private industry, and foreign entities. These instruments will all be delivered after completion of the LCLS line item project. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, has already identified a number of high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. Five specific areas of experimentation are: fundamental studies of the interaction of intense x-ray pulses with simple atomic systems; use of LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter. The combination of extreme brightness and short pulse length will make it possible to follow dynamical processes in chemistry and condensed matter physics in real time. It may also enable the determination of the structure of single biomolecules or small nanocrystals using only the diffraction pattern from a single moiety. This application has great potential in structural biology, particularly for important systems, such as membrane proteins, which are virtually uncharacterized by x-ray crystallography because they are nearly impossible to crystallize. Instrument teams will form to propose instruments to address these and other scientific areas of inquiry.

Construction funding provided in FY 2005 was for selected long-lead items, and the necessary refurbishment of existing space to provide for a magnet measurement facility for the testing of the long-lead equipment. Early acquisition of selected critical path items have supported pivotal schedule and technical aspects of the project. These include acquisition of the 135 MeV injector linac, acquisition of the undulator modules and the measurement system needed for verification of undulator performance, and acquisition of main linac magnets and radiofrequency systems required to produce electron beams meeting the stringent requirements of the LCLS FEL. Early acquisition of the 135 MeV injector was required to support initial tests of the FEL. Acquisition of the undulators in FY 2005 will enable their delivery in FY 2007. The main linac magnets and radiofrequency systems must be ready for operation shortly after the linac has reached its performance goals.

The FY 2006 funding supports physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Central Laboratory and Office Building. In addition, the injector will be completed and construction of the downstream linac and electron beam transport to the undulator hall will begin. Undulator module assembly will be started along with construction of x-ray transport/optics/diagnostics systems.

Construction funding requested in FY 2007 is for continuation of physical construction of the LCLS conventional facilities including the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, Far Experimental Hall, and the Central Laboratory and Office Building. In addition, the assembly and delivery of the undulators and undulator infrastructure to SLAC's Magnetic Measurement Facility is planned, as well as the procurements for the x-ray optics, diagnostics, and end stations. Delivery of the undulators in FY 2007 enables achievement of performance goals in FY 2009.

This project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3–1, Program and Project Management for the Acquisition of Capital Assets.

Compliance with Project Management Order:

- Critical Decision-0: Approve Mission Need—3Q FY 2001
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2003
- Critical Decision-2a: Approve Long-Lead Procurement Budget—3Q FY 2003
- Critical Decision-2b: Approve Performance Baseline—3Q FY 2005
- External Independent Review Final Report—3Q FY 2005
- Critical Decision-3a: Approve Start of Long-Lead Procurement—1Q FY 2005

- Critical Decision-3b: Approve Start of Construction—2Q FY 2006
- Critical Decision-4: Approve Start of Operations—2Q FY 2009

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
2003	5,925[a]	5,925[a]	3,644
2004	7,456[a]	7,456[a]	9,713
2005	19,914[a]	19,914[a]	18,388
2006	2,518[a]	2,518[a]	4,056
2007	161[a]	161[a]	173
Total, Design PED (03-SC-002)	35,974	35,974	35,974
Construction			
2005	29,760[bc]	29,760[bc]	19,959
2006	82,170[c]	82,170[c]	87,911
2007	105,740[c]	105,740[c]	107,000
2008	51,356[c]	51,356[c]	47,856
2009	10,000	10,000	16,300
Total, Construction	279,026	279,026	279,026
Total, TEC	315,000	315,000	315,000

[a] PED funding was reduced by $75,000 as a result of the FY 2003 general reduction and rescission, by $44,000 as a result of the FY 2004 rescission, by $161,000 as a result of the FY 2005 rescission, and by $26,000 as a result of the FY 2006 rescission. This total reduction is restored in FY 2005, FY 2006, FY 2007, and FY 2008 to maintain the TEC and project scope.

[b] FY 2005 funding was for long-lead procurements. The scope of work in FY 2005 was expanded to include modification of existing facilities at the Stanford Linear Accelerator Center for testing of the long-lead equipment items.

[c] Construction funding was reduced by $240,000 as a result of the FY 2005 rescission and by $830,000 as a result of the FY 2006 rescission. This total reduction is restored in FY 2007 and FY 2008 to maintain the TEC and project scope.

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design (PED 03-SC-002)	35,974	36,000
Construction Phase		
Site Preparation	9,000	9,000
Equipment	110,652	105,800
All other construction	93,400	93,400
Contingency	65,974	70,800
Total, Construction	279,026	279,000
Total, TEC	315,000	315,000

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning[a]	7,500	7,500
Start-up[b]	48,383	51,040
Contingency for OPC other than D&D	8,117	5,460
Total, OPC	64,000	64,000

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	35,801	173	—	—	—	—	—	35,974
TEC (Construction)	107,870	107,000	47,856	16,300	—	—	—	279,026
OPC Other than D&D	11,000	16,000	15,500	21,500	—	—	—	64,000
Total, Project Costs	154,671	123,173	63,356	37,800	—	—	—	379,000

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal year)	3Q FY 2009
Expected Useful Life (number of years)	30
Expected Future start of D&D for new construction (fiscal year)	N/A

[a] Costs in this category include NEPA, conceptual design, and R&D.
[b] Costs in this category include start-up (pre-operations) and spares.

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current Estimate[a]	Prior Estimate	Current Estimate[b]	Prior Estimate
Operations	25,000	N/A	—	N/A
Maintenance	25,000	N/A	—	N/A
Total Related Funding	50,000	N/A	1,909,000	N/A

FY 2010 is expected to be the first full year of LCLS facility operations. The current estimate is preliminary and based on historical experience with operating similar types and sizes of facilities. This estimate will be refined as the LCLS Project matures.

The estimate includes LCLS facility operations only. It does not include operation of the SLAC linac which is funded by HEP in FY 2005 and prior years, but begins a 3 to 4 year transition to BES funding beginning in FY 2006. Operation of the SLAC Linac is essential to the operation of the LCLS.

9. Required D&D Information

Not applicable.

10. Acquisition Approach

A Conceptual Design Report (CDR) for the project has been completed and reviewed. Key design activities are being specified in the areas of the injector, undulator, x-ray optics and experimental halls to reduce schedule risk to the project and expedite the startup. Also, the LCLS management systems have been put in place and tested during the Project Engineering Design (PED) phase. These activities are managed by the LCLS Project Office at SLAC, with additional portions of the project being executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL).

The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect (experimental halls, tunnel connecting the halls, and a Central Laboratory and Office Building) was contracted to an experienced Architect/Engineering (A/E) firm to perform Title I and II design. Title I design was completed in FY 2004. Title II design began in FY 2005.

[a] LCLS is currently under construction and normal operations are expected to begin in the 3Q FY 2009. The Annual Cost estimate shown in the table above is for a full year of operation.

[b] Assumptions: $379,000,000 TPC; $50,000,000 annual costs for 30 years; $30,000,000 de-commissioning.

05-R-321, Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, New York

1. Significant Changes

There have been no significant changes to scope, cost, or schedule.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006.......	4Q FY 2003	4Q FY 2004	3Q FY 2005	3Q FY 2008	N/A	N/A
FY 2007.......	4Q FY 2003	1Q FY 2005	4Q FY 2005	3Q FY 2008	N/A	N/A

3. Baseline and Validation Status

(dollars in thousands)

	TEC[a]	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs[a]	Validated Performance Baseline	Preliminary Estimate
FY 2006	79,700	1,300	N/A	81,000	81,000	N/A
FY 2007	79,700	1,300	N/A	81,000	81,000	N/A

4. Project Description, Justification, and Scope

This project will establish a Nanoscale Science Research Center (NSRC) at BNL. The scientific theme of the BNL Center for Functional Nanomaterials (CFN) is "atomic tailoring of functional nanomaterials to achieve a specific response." The CFN will be a user facility designed to provide a wide range of tools for the preparation and characterization of nanomaterials. The CFN will seek to integrate these unique capabilities with other BNL facilities, including the broad range of synchrotron characterization techniques available at the National Synchrotron Light Source (NSLS).

The CFN will be a new building, located across the street from the existing NSLS. Siting of the CFN will take advantage of close proximity to the Instrumentation Division and the Departments of Physics, Materials Science, and NSLS, which are key interdisciplinary participants in nanoscience research.

The design and scope of the CFN will fulfill DOE mission needs and incorporate input from potential users, gained through many channels including outreach efforts such as workshops. An essential component of the project is to establish an organizational infrastructure open to external users based on peer review. In this way a truly national nanomaterials effort can create breakthrough opportunities. The laboratory areas are organized into seven facilities established to provide the necessary primary user service. The facility theme functions cover a wide range of physical and chemical synthesis and characterization. They are designated Nanopatterning, Ultrafast Optical Sources, Electron Microscopy, Materials Synthesis, Proximal Probes, Theory and Computing, and CFN Endstations at NSLS. The CFN

[a] The full project TEC and TPC, established at Critical Decision 2 (Approve Performance Baseline), are $79,700,000 and $81,000,000 respectively, and include the cost for PED from project 02-SC-002.

will allow users to control processes, tailoring the properties of materials structured on the nanoscale. Some of these materials, all relevant to the BES mission, include piezoelectrics, ferroelectrics, organic films and conductors, magnetic nanocomposites, and catalysts.

The preliminary engineering and detailed engineering design necessary to construct a BNL Center for Functional Nanomaterials have been completed. The engineering effort included all engineering phase activities, including field investigation, preliminary design, specifications and drawings for conventional construction, final design, preparation of procurement documents for experimental equipment, and construction/equipment procurement estimates.

The completed design will enable construction of a new two-story Laboratory/Office building of approximately 94,500 gross square feet. The facility will include clean rooms, general laboratories, wet and dry laboratories for sample preparation, fabrication, and analysis. Included will be some of the equipment necessary to explore, manipulate and fabricate nanoscale materials and structures. Also included are individual offices and landscape office areas, seminar area, transient user space for visiting collaborators with access to computer terminals, conference areas on both floors, and vending/lounge areas. In addition, it will include circulation/ancillary space, including mechanical equipment areas, corridors, and other support spaces.

Technical procurement for the project will include an initial suite of laboratory equipment for the CFN laboratory themes: Nanopatterning, Ultrafast Optical Sources, Electron Microscopy, Materials Synthesis, Proximal Probes, and Theory and Computing as well as for the designated CFN Endstations at NSLS.

The building will incorporate human factors into its design to encourage peer interactions and collaborative interchange by BNL staff and CFN users and visitors. In addition to flexible office and laboratory space it will provide "interaction areas," a seminar room and a lunch room for informal discussions. This design approach is considered state-of-the-art in research facility design as it leverages opportunities for the free and open exchange of ideas essential to creative research processes.

The FY 2005 funds were used to begin conventional construction and technical equipment procurement. FY 2006 funds are being used to continue conventional construction and technical equipment procurement. The FY 2007 funds will be used to complete the building construction and procure additional technical equipment.

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets.

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2002
- Critical Decision-1: Approve Preliminary Baseline Range—4Q FY 2003
- External Independent Review (EIR) Final Report—April 28, 2004
- Critical Decision-2: Approve Performance Baseline—3Q FY 2004
- Critical Decision-3: Approve Start of Construction—4Q FY 2005
- Critical Decision-4a: Approve Building Occupation—3Q FY 2007
- Critical Decision-4b: Approve Start of Operations—3Q FY 2008

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
2003	988[a]	988[a]	733
2004	2,982[a]	2,982[a]	2,721
2005	1,996[a]	1,996[a]	1,555
2006	—	—	957
Total, Design PED (02-SC-002)	5,966	5,966	5,966
Construction			
2005	18,317[b]	18,317[b]	772
2006	36,187[b]	36,187[b]	34,079
2007	18,864[b]	18,864[b]	36,738
2008	366[b]	366[b]	2,145
Total, Construction	73,734	73,734	73,734
Total, TEC	79,700	79,700	79,700

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design (PED 02-SC-002)	5,966	5,966
Construction Phase		
Site Preparation	1,920	5,392
Equipment	21,279	26,097
All other construction	39,922	31,379
Contingency	10,613	10,866
Total, Construction	73,734	73,734
Total, TEC	79,700	79,700

[a] PED funding was reduced $12,000 as a result of the FY 2003 general reduction and rescission and by $18,000 as a result of the FY 2004 rescission. This total reduction/rescission is restored in FY 2005 and FY 2006 to maintain the TEC and project scope. A rescission reduced FY 2005 PED funding by $16,000.
[b] Construction funding was reduced by $148,000 as a result of the FY 2005 rescission and by $366,000 as a result of the FY 2006 rescission. This total reduction is restored in FY 2007 and FY 2008 to maintain the TEC and project scope.

Other Project Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Conceptual Planning	300	300
Start-up	1,000	1,000
Total, OPC	1,300	1,300

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC(Design)	5,966	—	—	—	—	—	—	5,966
TEC (Construction)	34,851	36,738	2,145	—	—	—	—	73,734
OPC Other than D&D	300	475	525	—	—	—	—	1,300
Total, Project Costs	41,117	37,213	2,670	—	—	—	—	81,000

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter)	3Q FY 2008[a]
Expected Useful Life (number of years)	40
Expected Future start of D&D for new construction (fiscal quarter)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life cycle costs	
	Current estimate	Prior Estimate	Current estimate	Prior Estimate
Operations	17,500	—	—	—
Maintenance	1,000	—	—	—
Total Related funding	18,500	—	821,000	—

9. Required D&D Information

Not applicable.

10. Acquisition Approach

Design and inspection of the facilities and equipment will be by the operating contractor and A/E subcontractor as appropriate. Technical construction will be competitively bid, lump sum contracts. To the extent feasible, construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bidding.

[a] Experimental research will begin at the time of Beneficial Occupancy of the facility. These research costs are not part of the TPC and will be provided by BES.

04-R-313, Molecular Foundry
Lawrence Berkeley National Laboratory, Berkeley, California

1. Significant Changes

There have been no significant changes to scope, cost, or schedule.

2. Design, Construction and D&D Schedule

(fiscal quarter)

	Preliminary Design Start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006	3Q 2002	1Q 2004	2Q 2004	1Q 2007	N/A	N/A
FY 2007	3Q 2002	1Q 2004	2Q 2004	1Q 2007	N/A	N/A

3. Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2006	83,700	1,300	—	85,000	85,000	N/A
FY 2007	83,604[a]	1,300	—	84,904[a]	84,904	N/A

4. Project Description, Justification and Scope

The Molecular Foundry at LBNL will be a new structure near the National Center for Electron Microscopy. The project includes an approximately 89,000 gross square foot research building, a separate approximately 6,000 gross square foot utility center, and an initial set of special equipment to support nanoscale scientific research. The research building will be an advanced facility with state-of-the-art clean rooms for the design, modeling, synthesis, processing, fabrication and characterization of novel molecules and nanoscale materials. Space in the new facility will support studies in nanostructures by providing offices and laboratories for materials science, physics, chemistry, biology, and molecular biology. These laboratories, equipped with advanced instrumentation and staffed by full-time, dedicated staff scientists and technicians, will be user facilities, available to scientists from universities, industry, and government laboratories whose research proposals will have been peer reviewed by a Proposal Study Panel. This combination of advanced equipment, collaborative staff, and breadth across disciplines will allow users to explore the frontiers of nanoscience.

The goals and operation of the Molecular Foundry are consistent with DOE guidance and address the research challenges described in the reports *Nanoscale Science, Engineering and Technology Research Directions and Complex Systems: Science for the 21st Century*. The Foundry's laboratories will be designed and constructed to facilitate collocation of research activities in a wide variety of fields, as required for progress in this new area of science. The Foundry will support a broad research effort

[a] The TEC and TPC have been reduced by $96,000 due to the FY 2006 rescission, and includes the costs for PED from project 02-SC-002.

focusing on both "hard" nanomaterials (nanocrystals, tubes, and lithographically patterned structures) and "soft" nanometer-sized materials (polymers, dendrimers, DNA, proteins, and whole cells), as well as design, fabrication, and study of multi-component, complex, functional assemblies of such materials.

By functioning as a "portal" to Lawrence Berkeley National Laboratory's established major user facilities, the Foundry will also leverage existing nanoscience research capabilities at the Advanced Light Source, the National Center for Electron Microscopy, and the National Energy Research Scientific Computing Center. The research program will, as an additional benefit, provide significant educational and training opportunities for students and postdoctoral fellows as the "first true generation" of nanoscientists.

FY 2004 funding was used to initiate construction to complete site preparation, and for equipment procurement. FY 2005 and FY 2006 funding is being used to complete conventional construction and begin equipment procurement. FY 2007 funding will be used to complete equipment procurement and installation.

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
2002	500	500	38
2003	6,715[a]	6,715[a]	5,263
2004	—	—	1,896
2005	—	—	18
Total, Design (PED No. 02-SC-002)	7,215	7,215	7,215
Construction			
2004	34,794[b]	34,794[b]	10,970
2005	31,828[bc]	31,828[bc]	37,626
2006	9,510[cd]	9,510[cd]	26,923
2007	257[c]	257[c]	870
Total, Construction	76,389	76,389	76,389
Total TEC	83,604	83,604	83,604

[a] PED funding was reduced by $85,000 as a result of the FY 2003 general reduction and rescission. This total reduction/rescission was restored in FY 2005 to construction to maintain the TEC and project scope.
[b] Construction funding was reduced by $207,000 as a result of the FY 2004 rescission and by $257,000 as a result of the FY 2005 rescission.
[c] This total reduction is restored FY 2006 and FY 2007 to maintain the TEC and project scope.
[d] Construction was reduced by $96,000 as a result of the FY 2006 rescission.

6. Details of Project Cost Estimate

Total Estimated Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Preliminary and Final Design (PED 02-SC-002)	7,215	7,215
Construction Phase		
Building & Improvements to land	52,106	49,444
Special Equipment[a]	17,082	15,056
All other construction	4,236	3,863
Contingency	2,965	8,122
Total, Construction	76,389	76,485
Total, TEC	83,604	83,700

Other Project Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Conceptual Planning	932	932
Start-up	368	368
Total, OPC	1,300	1,300

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	7,215	—	—	—	—	—	—	7,215
TEC (Construction)	75,519	870	—	—	—	—	—	76,389
OPC Other than D&D	1,300	—	—	—	—	—	—	1,300
Total Project Costs	84,034	870	—	—	—	—	—	84,904

[a] Initial research equipment.

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal year)	1Q FY 2007[a]
Expected Useful Life (number of years)	40
Expected Future start of D&D for new construction (fiscal year)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual costs		Life cycle costs	
	Current Estimate	Previous Estimate	Current Estimate	Previous Estimate
Operations	18,105	N/A	—	N/A
Maintenance	395	N/A	—	N/A
Total Related funding	18,500	N/A	835,000	N/A

9. Required D&D Information

Not applicable. This project received construction funding starting in FY 2004. The project includes 95,000 gsf of new construction which was offset by banked excess space that had been previously eliminated.

10. Acquisition Approach

An Architect Engineering firm (AE) with appropriate multi-disciplinary design experience has prepared a building program and design criteria with the support of the LBNL Facilities Department. The AE also prepared preliminary and final design and is providing technical oversight during construction. A Construction Management (CM) contractor performed cost, schedule, and constructability reviews during design. Selection of the CM contractor during the design phases was based on competitive bidding of the Construction General Conditions. The CM contract had an option for management of the construction process. At the completion of design, the CM contractor bid out the design to subcontractors. The University has exercised its option to proceed with the CM contractor. Construction subcontract(s) were awarded on a competitive basis using best value source selection criteria that included price, safety, and other considerations.

[a] Fiscal quarter designated corresponds to start of full operations and completion of project. Initial operations (experimental research) with a limited suite of special equipment will begin earlier; these research costs are not part of the TPC and will be funded by the BES program.

03-SC-002, Project Engineering and Design (PED), Linac Coherent Light Source, Stanford Linear Accelerator Center

1. Significant Changes

There have been no significant changes to scope, cost, or schedule.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design Start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006	2Q FY 2003	4Q FY 2006	N/A	N/A	N/A	N/A
FY 2007	2Q FY 2003	4Q FY 2006	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2006	36,000	7,500	—	43,500	N/A	N/A
FY 2007	35,974[b]	7,500	—	43,474[b]	N/A	N/A

4. Project Description, Justification and Scope

These funds allowed the Linac Coherent Light Source (LCLS), located at the Stanford Linear Accelerator Center (SLAC), to proceed from conceptual design into preliminary design and definitive design. The design effort has been sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements. The design effort has ensured that long-lead procurement items could be initiated and construction could physically start to support the baseline LCLS schedule.

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 brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project will provide the first demonstration of an x-ray free-electron-laser (FEL) in the 1.5–15 Angstrom range and will apply these extraordinary, high-brightness x-rays to an initial set of scientific problems. This will be the world's first such facility.

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[a] Construction funding for this project is included in project 05-R-320. The estimates in section 3 are for PED only. The full project TEC and TPC, established at Critical Design 2 (Approve Performance Baseline), are $315,000,000 and $379,000,000, respectively.
[b] The TEC and TPC have been reduced by $26,000 due to the FY 2006 rescission.

The LCLS is based on the existing SLAC linac. The SLAC linac can accelerate electrons or positrons to 50 GeV for colliding beam experiments and for nuclear and high-energy physics experiments on fixed targets. At present, the first two-thirds of the linac is being used to inject electrons and positrons into PEP-II, and the entire linac is used for fixed target experiments. When the LCLS is completed, the latter activity will be limited to 25 percent of the available beam time and the last one-third of the linac will be available for the LCLS a minimum of 75 percent of the available beam time. For the LCLS, the linac will produce high-brightness 5–15 GeV electron bunches at a 120 Hz repetition rate. When traveling through the new 120-meter long LCLS undulator, these electron bunches will amplify the emitted x-ray radiation to produce an intense, coherent x-ray beam for scientific research.

The LCLS makes use of technologies developed for the SLAC and the next generation of linear colliders, as well as the progress in the production of intense electron beams with radiofrequency photocathode guns. These advances in the creation, compression, transport, and monitoring of bright electron beams make it possible to base this next generation of x-ray synchrotron radiation sources on linear accelerators rather than on storage rings.

The LCLS will have properties vastly exceeding those of current x-ray sources (both synchrotron radiation light sources and so-called “table-top” x-ray lasers) in three key areas: peak brightness, coherence (i.e., laser-like properties), and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons, providing over 10^{11} x-ray photons in a pulse with duration of less than 230 femtoseconds. These characteristics of the LCLS will open new realms of scientific applications in the chemical, material, and biological sciences. The LCLS Scientific Advisory Committee, working in coordination with the broad scientific community, identified high priority initial experiments that are summarized in the document, *LCLS: The First Experiments*. These first five areas of experimentation are: fundamental studies of the interaction of intense x-ray pulses with simple atomic systems; use of the LCLS to create warm dense matter and plasmas; structural studies on single nanoscale particles and biomolecules; ultrafast dynamics in chemistry and solid-state physics; and studies of nanoscale structure and dynamics in condensed matter.

The experiments fall into two classes. The first follows the traditional role of x-rays to probe matter without modifying it, while the second utilizes the phenomenal intensity of the LCLS to excite matter in fundamentally new ways and to create new states in extreme conditions. The fundamental studies of the interactions of intense x-rays with simple atomic systems are necessary to lay the foundation for all interactions of the LCLS pulse with atoms embedded in molecules and condensed matter. The structural studies of individual particles or molecules make use of recent advances in imaging techniques for reconstructing molecular structures from diffraction patterns of non-crystalline samples. The enormous photon flux of the LCLS may make it feasible to determine the structure of a *single* biomolecule or small nanocrystal using only the diffraction pattern from a single moiety. This application has enormous potential in structural biology, particularly for important systems such as membrane proteins, which are virtually uncharacterized by x-ray crystallography because they are nearly impossible to crystallize. The last two sets of experiments make use of the extremely short pulse of the LCLS to follow dynamical processes in chemistry and condensed matter physics in real time. The use of ultrafast x-rays will open up entire new regimes of spatial and temporal resolution to both techniques.

The LCLS Project requires a 135 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 undulator and associated equipment. Two new buildings, the Near Experimental Hall and the Far Experimental Hall will be constructed and connected by a beam line tunnel. A Central Laboratory and Office Building will be constructed to provide laboratory and office space for LCLS users and serve as a center of excellence for basic research in x-ray physics and ultrafast science.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3 -1, Program and Project Management for the Acquisition of Capital Assets.

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2001
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2003
- Critical Decision-2a: Approve Long-Lead Procurement Budget—3Q FY 2003
- Critical Decision-2b: Approve Performance Baseline—3Q FY 2005
- External Independent Review Final Report—3Q FY 2005
- Critical Decision 3a: Approve Start of Long-Lead Procurement—1Q FY 2005
- Critical Decision-3b: Approve Start of Construction—2Q FY 2006
- Critical Decision-4: Approve Start of Operations—2Q FY 2009

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2003	5,925 [a]	5,925 [a]	3,644
2004	7,456 [a]	7,456 [a]	9,713
2005	19,914 [a]	19,914 [a]	18,388
2006	2,518 [ab]	2,518 [ab]	4,056
2007	161 [a]	161 [a]	173
Total, Design PED (03-SC-002)	35,974	35,974	35,974

[a] PED funding was reduced as a result of the FY 2003 general reduction and rescission by $75,000, as a result of the FY 2004 rescission by $44,000, and as a result of the FY 2005 rescission by $161,000. This total reduction is restored in FY 2005, FY 2006, and FY 2007 to maintain the TEC and project scope.
[b] PED funding was reduced by $26,000 as a result of the FY 2006 rescission.

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design	35,974	35,974

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning	1,500	1,500
R&D	6,000	6,000
Total, OPC	7,500	7,500

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	35,801	173	—	—	—	—	—	35,974
OPC (Design)	7,500	—	—	—	—	—	—	7,500
Total, Project Costs	43,301	173	—	—	—	—	—	43,474

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

A Conceptual Design Report (CDR) for the project was completed and reviewed in FY 2002. Key design activities are being specified in the areas of the injector, undulator, x-ray optics and experimental halls to reduce schedule risk to the project and expedite the startup. Also, the LCLS management systems have been being put in place and tested during the Project Engineering and Design (PED) phase. These activities are managed by the LCLS Project Office at SLAC, with additional portions of the project being executed by staff at Argonne National Laboratory (ANL) and Lawrence Livermore National Laboratory (LLNL).

The design of technical systems is being accomplished by the three collaborating laboratories. The conventional construction design aspect (experimental halls, tunnel connecting the halls, and a Central Laboratory and Office Building) was contracted to an experienced Architect/Engineering (A/E) firm to perform preliminary and final design. Preliminary design was completed in FY 2004. Final design began in FY 2005 and will be complete by the end of FY 2006.

03-R-313[a], The Center for Integrated Nanotechnologies (CINT) Facility Sandia National Laboratories, Albuquerque, New Mexico, and Los Alamos National Laboratory, Los Alamos, New Mexico

1. Significant Changes

There have been no significant changes to scope, cost, or schedule.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006…	4Q FY 2002	2Q FY 2004	1Q FY 2004	3QFY 2007	N/A	N/A
FY 2007…	4Q FY 2002	2Q FY 2004	1Q FY 2004	3Q FY 2007	N/A	N/A

3. Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2006...	73,800	2,000	—	75,800	75,800	N/A
FY 2007...	73,754[b]	2,000	—	75,754[b]	75,754	N/A

4. Project Description, Justification, and Scope

This project provides materials and services required to design and construct the proposed Center for Integrated Nanotechnologies (CINT) Facility. CINT is one of the five BES/Office of Science Nanoscale Science Research Centers (NSRCs). It will be operated jointly by Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL). CINT is a U.S. Department of Energy (DOE) line item project that is being carried out as a partnership between SNL and LANL to design and build a world-class user facility for research in nanoscale science. The partnership between two world-class DOE laboratories, each with significant technical expertise and capability in nanoscale research, will provide the best possible facility to the nanoscience research community.

CINT will be a distributed Center that is jointly operated by SNL and LANL. Its primary objective is to develop the scientific principles that govern the performance and integration of nanoscale materials, thereby building the foundations for future nanotechnologies. The distinguishing characteristic of the Center is its focus on exploring the path from scientific discovery to the integration of nanostructures into the micro and 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. This Center works closely with the other NSRCs to ensure that their

[a] This project was submitted in the FY 2004 President's Request as project 04-R-314. In FY 2003 Congress appropriated construction funds for this project (after the FY 2004 Request was submitted to Congress) under project 03-R-313.
[b] The full project TEC and TPC established at Critical Decision 2 (Approve Performance Baseline) are $73,754,000 and $75,754,000, respectively and include the costs for PED from project 02-SC-002. TEC and TPC are reduced by $46,000 as a result of the FY 2006 rescission.

discoveries are evaluated in the context of integrated functional systems. This approach offers a unique role for the DOE in support of the National Nanotechnology Initiative.

The managements of the Los Alamos and Sandia National Laboratories are committed to develop CINT as a DOE national resource for the advancement of nanoscience and technology. Through its laboratory partnership, CINT will leverage expertise and facilities from both SNL and LANL and make those resources available to the user community. In order to provide a strong central focus for the user community while also providing extraordinary leverage and access to existing laboratory capabilities, the CINT project, in conjunction with its user community, has developed a unique Core/Gateway structure.

The Core Facility (approximately 95,000 gross square feet), which will be constructed in Albuquerque, will be the single point of entry for the CINT user community and will provide the multi-disciplinary research environment needed to explore scientific challenges associated with nanoscience integration. In order to assure open access to the user community, the Core Facility is being constructed on DOE property outside of the Kirtland Air Force Base (KAFB).

In addition to developing the Core Facility, the CINT user community strongly recommended that the CINT project also provide access to the deep and broad resources of both SNL and LANL. The Gateway Facilities at both SNL and LANL are designed to provide the user community with direct access to existing DOE/SC and DOE/NNSA programmatic investments at each laboratory.

The Gateway to Sandia Facility is housed within an existing space in an NNSA building located on the main campus within the KAFB. The Gateway to Sandia, which will provide office and laboratory space for CINT users, is co-located with many of Sandia's existing facilities for nanoscale science research and Sandia's world-class microfabrication facilities. No new construction is required for the Gateway to Sandia since it will utilize existing NNSA space. (While the NNSA facility that houses the Gateway to Sandia is within the KAFB boundaries, it is located outside classified restricted boundaries and is therefore open for general user access).

Development of the Gateway to Los Alamos Facility (approximately 34,000 gross square feet) involves the construction of a new building on the Los Alamos campus providing the user community direct access to existing nanoscale materials science and bioscience capabilities. The Gateway to Los Alamos Facility is located in the center of the Los Alamos materials science complex which is in an open security environment and will facilitate easy access to these existing nanoscale materials science and bioscience resources. Traditionally, materials science and bioscience have been viewed as separate activities and are housed primarily in separate parts of the Los Alamos campus. The Gateway to Los Alamos will provide a unique research environment for CINT users by combining nanoscale materials science and biosciences capabilities and expertise under one roof surrounded by supporting resources accessible to CINT users.

The CINT project is building a unified community around its Core Facility and two Gateway Facilities (one each at SNL and LANL). The CINT project is using public workshops, presentations at scientific forums, web-based communications, and one-on-one interactions with CINT scientists to help build its user community with significant participation from university, industrial, and laboratory researchers. Input and advice from the user community is used to help define and refine the proper tools and scientific focus to address the challenges of nanoscale science and technology. CINT is focused on *integration* because it is the key factor in the scientific development and application of nanoscience. The tools and resources of CINT will be available at no cost to university, industrial, and laboratory researchers through a peer-reviewed process. The external scientific community has been and will continue to be a vital partner in developing CINT so that it is successful in achieving its vision.

The initial technical focus of the Center will be on the following five thrusts:

- Nanophotonics and Nanoelectronics
- Complex Functional Nanomaterials
- Nanomechanics
- Nanoscale and Bio-Microinterfaces
- Theory and Simulation

This laboratory and office space complex will house state-of-the-art clean rooms and equipment for nanolithography, atomic layer deposition, and materials characterization along with general purpose chemistry and electronics labs and offices for Center staff and collaborators.

The CINT Core Facility will include class 1,000 clean room space for nanofabrication and characterization equipment and class 100 clean room space for lithography activities. This facility will also require general purpose chemistry/biology laboratories, electronic and physical measurement laboratories, office and meeting room space.

The scope of this project is to construct the CINT Core and Gateway to Los Alamos. The engineering effort includes preliminary and final design of both buildings. The project also includes procurement of an initial set of experimental capital equipment and construction of facilities. FY 2003, FY 2004, and FY 2005 construction funds were used for conventional construction and equipment procurement. FY 2006 and FY 2007 construction funds will be used to continue these activities.

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets.

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2001
- Critical Decision-1: Approve Preliminary Baseline Range—3Q FY 2002
- Critical Decision-2: Approve Performance Baseline—4Q FY 2003
- External Independent Review Final Report—4Q FY 2003
- Critical Decision-3: Approve Start of Construction—1Q FY 2004
- Critical Decision-4a: Approve Start of Initial Operations—3Q FY 2006
- Critical Decision-4b: Approve Start of Full Operations—3Q FY 2007

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
2002	1,000	1,000	167
2003	3,159[a]	3,159[a]	3,319
2004	—	—	562
2005	—	—	111
Total, Design PED (02-SC-002)	4,159	4,159	4,159
Construction			
2003	4,444[b]	4,444[b]	—
2004	29,674[b]	29,674[b]	6,946
2005	30,650[ab]	30,650[ab]	40,857
2006	4,580[bc]	4,580[bc]	15,330
2007	247[b]	247[b]	6,462
Total, Construction	69,595	69,595	69,595
Total TEC	73,754	73,754	73,754

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design(PED 02-SC-002)	4,159	4,159
Construction Phase		
Site Preparation	1,430	1,430
Equipment	14,002	13,861
All other construction	48,950	45,158
Contingency	5,213	9,192
Total, Construction Costs	69,595	69,641
Total, TEC	73,754	73,800

[a] PED funding was reduced $41,000 as a result of the FY 2003 general reduction and rescission. This total reduction/rescission was restored to construction in FY 2005 to maintain the TEC and project scope.
[b] Construction funding was reduced by $56,000 as a result of the FY 2003 general reduction and rescission, by $176,000 as a result of the FY 2004 rescission, and by $247,000 as a result of the FY 2005 rescission. This total reduction is restored in FY 2005, FY 2006, and FY 2007 to maintain the TEC and project scope.
[c] Construction funding was reduced by $46,000 as a result of the FY 2006 rescission.

Other Project Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Conceptual Planning	800	800
Start-up	1,200	1,200
Total, OPC	2,000	2,000

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	4,159	—	—	—	—	—	—	4,159
TEC (Construction)	63,133	6,462	—	—	—	—	—	69,595
OPC Other than D&D	2,000	—	—	—	—	—	—	2,000
Total Project Costs	69,292	6,462	—	—	—	—	—	75,754

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter)	3Q FY 2007[a]
Expected Useful Life (number of years)	40
Expected Future start of D&D for new construction (fiscal quarter)	N/A

(Related Funding Requirements)

(dollars in thousands)

	Annual Costs		Life Cycle Costs	
	Current estimate	Previous Estimate	Current estimate	Previous Estimate
Operations	18,000	N/A	—	N/A
Maintenance	500	N/A	—	N/A
Total Related funding	18,500	N/A	830,800	N/A

9. Required D&D Information

Not applicable. This project received construction funding starting in FY 2003. The project includes approximately 95,000 gsf of new construction at SNL and approximately 34,000 gsf of new construction at LANL, which was offset by banked excess space.

[a] Fiscal quarter designated corresponds to start of full operations and completion of project. Initial operations (experimental research) with a limited suite of special equipment will begin earlier; these research costs are not part of the TPC and will be funded by the BES program.

10. Acquisition Approach

Preliminary and final design for the Core Facility was accomplished through the use of a firm fixed-price contract with a qualified and experienced A/E firm. The selection was made under the SNL Best Value Contracting Procedures. The construction contract for the Core Facility has been awarded under a fixed-price contract using the SNL Best Value Contracting Procedures.

The design and construction of the Gateway to Los Alamos Facility is being accomplished through the use of a firm fixed-price Design-Build contract with a qualified and experienced construction-A/E firm. The selection was made under the LANL Best Value Contracting Procedures using LANL developed Performance Specifications to solicit proposals from interested firms.

Procurement of the initial set of experimental capital equipment for both facilities is being carried out at SNL using standard corporate procurement processes. Fixed price contracts are awarded for the instruments after Best Value Contracting Procedures are used to select the vendors.

Advanced Scientific Computing Research

Funding Profile by Subprogram

	(dollars in thousands)				
	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	226,180[a]	237,055	-2,371[b]	234,684	318,654

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act"
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, leadership in scientific computation has become a cornerstone of the Department's strategy to ensure the security of the nation and succeed in its science, energy, environmental quality, and national security missions.

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 understand and 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 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. Computational science is increasingly central to progress at the frontiers of almost every scientific discipline and to our most challenging feats of engineering.

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[a] Total is reduced by $1,872,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $5,614,000, which was transferred to the SBIR program; and $674,000, which was transferred to the STTR program.
[b] Reflects a rescission in accordance with P.L. 109-148, The Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

Strategic and Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the mission) plus seven general goals that tie to the strategic goals. The ASCR program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

The ASCR program has one program goal which contributes to General Goal 5 in the "goal cascade":

Program Goal 05.23.00.00: 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 Program Goal 05.23.00.00 (Deliver forefront computational and networking capabilities)

The ASCR program contributes to Program Goal 05.23.00.00 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 to deliver extraordinary science. Applied Mathematics enables scientists to build models of physical and natural systems with extraordinary fidelity, 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 critical to advance the frontiers of simulation. Shrinking the distance between scientists and the resources they need is also critical to 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 General Goal 5 by enabling research programs across SC, as well as other elements of the Department, to succeed. The following indicators establish specific long term (10 years) goals in Scientific Advancement that the ASCR program is committed to, and progress can be measured against:

- Develop multiscale mathematics, numerical algorithms, and software that enable 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.23.00.00, Deliver forefront computational and networking capabilities (Advanced Scientific Computing Research)..............	226,180	234,684	318,654

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 05.23.00.00 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]	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 2006— >50%	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— >50%
	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]	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 2006— 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 2007— 40%

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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 leadership of the 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 Administration [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 Computing Information and Communications Research and Development (R&D) subcommittee of the National Science and Technology Council (NSTC), under the auspices of SC and Technology Policy. This coordination is periodically reviewed by the President's Information Technology Advisory Committee (PITAC). 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 Science 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)

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 FY 2005 PART review, OMB gave the ASCR program an overall rating of "Moderately Effective." 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 is 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 2007. 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. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report. In response to PART findings, ASCR established a Committees of Visitors (COV) to provide outside expert validation of the program's merit-based review processes for impact on quality, relevance, and performance. ASCR has received the reports from the first COV, which focused on the research programs, and the second COV, which met April 5-6, 2005, to review the facilities and network research efforts, and is working on an action plan to respond to the recommendations. In order to address specific concerns ASCR has made plans in FY 2006 and future fiscal years to: engage advisory panel and other outside groups in regular, thorough scientific assessments of the quality, relevence, and performance of its research portfolio and computing/network facilities; engage 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; and to implement action plans to improve program management in response to past expert reviews.

For the FY 2007 Budget, OMB has developed PARTWeb – a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the website http://ExpectMore.gov and will improve public access to PART assessments and follow up actions. For 2006 there are three 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, ASCR will charge the Advanced Scientific Computing Research Advisory Committee to review progress toward the long term goals of the program before the end of FY 2006 and will continue to host Committees of Visitors (CoV) and other panels to review the quality, relevance, and performance of the program. ASCR will continue to publish responses to the COV's findings and will track improvements at http://www.sc.doe.gov/measures/FY06.html.

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.

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. As stated in the "Analytical Perspectives" of the FY 2004 Budget:

> Due to its impact on a wide range of federal agency missions ranging from national security and defense to basic science, high-end computing—or supercomputing—capability is becoming increasingly critical. Through the course of 2003, agencies involved in developing or using high-end computing will be engaged in planning activities to guide future investments in this area, coordinated through the National Science and Technology Council (NSTC). The activities will include the development of interagency R&D roadmaps for high-end computing core technologies, a federal high-end computing capacity and accessibility improvement plan, and a discussion of issues (along with recommendations where applicable) relating to federal procurement of high-end computing systems. The knowledge gained from this process will be used to guide future investments in this area. Research and software to support high-end computing will provide a foundation for future federal R&D by improving the effectiveness of core technologies on which next generation high-end computing systems will rely.

To address these issues the President's Science Advisor chartered the High End Computing Revitalization Task Force (HECRTF), which developed a plan for a Federal research program to address these issues. This task force was co-chaired by SC and the Department of Defense (DOD). ASCR's efforts in computer science, research and evaluation prototypes, high performance production computing (NERSC), and the Leadership Computing Facilities (LCFs) are important components of the interagency implementation of this plan.

How We Work

The ASCR program uses a variety of mechanisms for conducting, coordinating, and funding research in applied mathematics, network and computer sciences, and in advanced computing software tools. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting core university and national laboratory programs, and maintaining a strong infrastructure to support research in applied mathematics, network and computer science, and advanced computing software tools. 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)—though inactive in 2005—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 Interagency Principals Group, chaired by the President's Science Advisor, and the Information Technology Working Group (ITWG). 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 the President's Science Advisor.

In addition, ASCR, both through ASCAC and independently, supported a number of workshops to support its planning. These include:

- Blueprint for Future Science Middleware and Grid Research and Infrastructure, August 2002;
- DOE Science Network Meeting, June 2003 (http://gate.hep.anl.gov/may/ScienceNetworkingWorkshop/);

- DOE Science Computing Conference, June 2003 (http://www.doe-sci-comp.info);
- Science Case for Large Scale Simulation, June 2003;
- Workshop on the Road Map for the Revitalization of High End Computing (http://www.cra.org/Activities/workshops/nitrd/);
- Cyber Infrastructure Report (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=cise051203);
- "Federal Plan for High-End Computing, report of the High End-Computing Revitalization Task Force (HECRTF)" (http://www.itrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf); and
- The Office of Science Data-Management Challenge, Report from the DOE Office of Science Data-Management Workshops (http://www.sc.doe.gov/ascr/Final-report-v26.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 2,000 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. Allocations of computer time and archival storage at NERSC are awarded to research groups based on a review of submitted proposals. As proposals are submitted, they are subjected to peer review to evaluate the quality of science, the relevance of the proposed research to 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, 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. A pioneer in providing DOE mission-oriented high-bandwidth, reliable connections, 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. The ESnet Steering Committee (ESSC) was established in 1985 to ensure that ESnet meets the needs of SC programs. All program offices in SC appoint a representative to serve on the ESSC. The ESSC is responsible for reviewing and prioritizing network requirements, for establishing performance objectives, and for proposing innovative techniques for enhancing ESnet capabilities. In addition to the ongoing oversight from the ESSC, ASCR conducts regular external peer reviews of ESnet performance. The last such review was chaired by a member of ASCAC and took place in September 2001. The next review is scheduled in 2006.

In FY 2002, ASCAC conducted a review of ASCR's high performance computing facilities. The charge to ASCAC, posed the following questions:

- What is the overall quality of these activities relative to the best-in-class in the U.S. and internationally?
- How do these activities relate and contribute to Departmental mission needs?
- How might the roles of these activities evolve to serve the missions of the SC over the next three to five years?

The essential finding of the Subcommittee was that these facilities are among the best worldwide. It was the opinion of the Subcommittee that these ASCR activities and the related spin-off research efforts contribute significantly to the mission needs of DOE, and profoundly and positively impact high performance computing activities worldwide. The complete report is available on the web. (http://www.science.doe.gov/ascr/ASCAC-sub.doc).

In FY 2004, ASCR conducted a peer review of the CCS evaluation of the Cray X1 computer. The results from this review validated the exceptionally 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 Leadership Computing Facility (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, the SC Project Assessment group conducted a formal Baseline validation review of the ORNL LCF.

Program Reviews

The ASCR program conducts frequent and comprehensive evaluations of every component of the program. Results of these evaluations are used to modify program management as appropriate.

In FY 2003, ASCR conducted a peer review of the Numerical Linear Algebra, Optimization, and Predictability Analysis areas within the Applied Mathematics activity. These areas represent 33% of this activity. In FY 2004, ASCR conducted a peer review of the Differential Equations and Advanced Numerical Methods for High Performance Computing areas within the Applied Mathematics activity, representing an additional 33% of this activity. In FY 2005, ASCR conducted a peer review of the remaining 34% of the Applied Mathematics activity, which consisted of Computational Fluid Dynamics and Meshing Techniques. Also, in FY 2003 ASCR completed reviews of all of the SciDAC Integrated Software Infrastructure Centers (ISICs). There are a total of seven such centers (three with a mathematics focus and four with a computer science focus), and this represents over 50% of the ASCR SciDAC budget.

In FY 2003, ASCR also conducted peer reviews of all the SciDAC Collaboratory Pilot and Middleware Projects. These reviews focused on accessing progress and the possible need for mid-course corrections.

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:

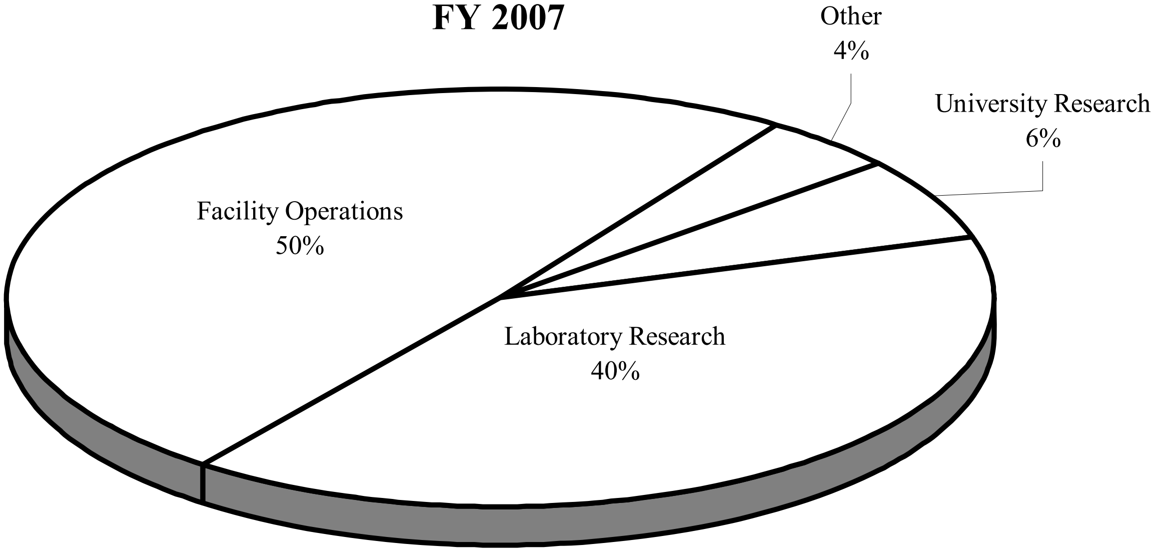
- The Department and SC Strategic Plan, as updated through program collaborations and joint advisory committee meetings (http://www.sc.doe.gov/Sub/Mission/mission_strategic.htm);
- SciDAC plan delivered to Congress in March 2000 (http://www.science.doe.gov/scidac/);
- ASCAC report on the Japanese Earth Simulator (http://www.sc.doe.gov/ascr/ascac_reports.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 2007 budget request continues the core and SciDAC research efforts and strengthens the research partnerships with other SC offices. Network operations expenditures account for 22% of the national laboratory research. The LTR subprogram was brought to a successful completion in FY 2004.

Advanced Scientific Computing Research Budget Allocation FY 2007



Research

46 percent of the ASCR program's FY 2007 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. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2005, the ASCR program supported over 150 grants to the nation's university researchers and graduate students engaged in civilian applied mathematics, large-scale network and computer science research. 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 2005, CSGF activity selected 15 new graduate students representing 12 universities and 8 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 12 awards to early career principal investigators in FY 2005.

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. ASCR funds the best among the ideas submitted in response to grant solicitation notices (http://www.sc.doe.gov/grants/grants.html). 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 and novel applications of high performance computing 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 advances mathematics and computer science, and develops the specialized algorithms, the scientific software tools, and the software libraries needed by DOE researchers to effectively use high-performance computing and networking hardware for scientific discovery. The ASCR program has been a leader in the computational sciences for several decades and has been acknowledged for pioneering accomplishments. The FY 2007 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 are being recompeted in FY 2006, with attention paid to support for the long term maintenance and support 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. In addition, in FY 2006 ASCR is changing the way in which it manages its Genomics: GTL partnership with BER. The management of these efforts will be integrated into the portfolio of successful SciDAC partnerships. Finally, in FY 2007 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.

For the past two decades SC, and the worldwide scientific community, have been harvesting their success in building and developing the Internet. This has enabled roughly a doubling in bandwidth every two years with no increase in cost. However, the demands of today's facilities, which generate millions of gigabytes per year of data, now outstrip the capabilities of the Internet design. 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 possibility of exploiting these technologies to provide scientific data where it is needed at speeds commensurate with the new data volumes. However, to take advantage of this opportunity significant research is needed to integrate these capabilities, make them available to scientists, and build the infrastructure which can provide cybersecurity in this environment.

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 the NSTC and OSTP. This area has been identified as a priority within the overall Networking and Information Technology Research and Development (NITR&D) priorities of the Administration. In prior budgets some, but not all, of the activities related to the HECRTF plan were described as components of the Next Generation Architecture (NGA) effort. We have eliminated discussion of the NGA to enable a clearer description of how ASCR research and facilities contribute to the HECRTF plan.

In FY 2007, further diversity with the LCF resources will be 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. This capability will accelerate scientific understanding in areas that include materials science, biology, and advanced designs of nuclear reactors.

These changes were made to guarantee 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 NITR&D subcommittee of the National Science and Technology Council and its Technology Committee. The NITR&D subcommittee evolved through an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. The NITR&D Subcommittee provides hands-on coordination for the multiagency NITR&D Program. The Subcommittee is made up of representatives from each of the participating NITR&D agencies and from the Office of Management and Budget (OMB), the NSTC, and the National Coordination Office for IT R&D (NCO/IT R&D). The Subcommittee coordinates planning, budgeting, and assessment activities of the multiagency NITR&D 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. The DOE program solves mission critical problems in scientific computing. In addition, results from the DOE program benefit the Nation's information technology basic research effort. The FY 2007 program positions DOE to make additional contributions to this effort. In the area of high performance computing and computation, ASCR has extensive partnerships with other Federal agencies and the NNSA. Examples include: participating in the program review team for the DARPA High Productivity Computing Systems program; serving on the planning group for the Congressionally mandated DOD plan for high performance computing to serve the national security mission; serving on the OSTP High End Computing Revitalization Task Force; and extensive collaboration with NNSA-Advanced Simulation 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.

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. 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 to 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.

The research focus of ASCR SciDAC activities includes Integrated Software Infrastructure Centers (ISICs). ISICs are partnerships between DOE national laboratories and universities focused on research, development, and deployment of software to accelerate the development of SciDAC application codes. Progress to date includes significant improvements in performance modeling and analysis capabilities that have led to doubling the performance on 64 processors of the Community Atmosphere Model component of the SciDAC climate modeling activity. The three Mathematics ISICs were begun in 2001 to bring a new level of mathematical sophistication to computational problems throughout SC. One of these, the Terascale Optimal Partial Differential Equations (PDE) Simulations (TOPS) Center, is combining the Hyper and Portable Extensible Toolkit for Scientific Computation (PETSC) libraries, together with newly developed algebraic multigrid solvers, to create fast algorithms for a variety of tough and important problems, including biochemical reaction diffusion equations and advection equations for combustion simulation. The Terascale Simulation Tools and Technologies Center is working to develop a framework for coupling different types of grids together in a single application. For example, in a simulation of engine combustion, one might want an unstructured grid for the complex geometry around the valves, but a regular grid in the rest of the cylinder. Finally, the Applied Partial Differential Equations Center is focused on using structured adaptive grids for simulation in a variety of application domains, including ground water flow, combustion chemistry, and magneto-hydrodynamics. Given the difficulty of magneto-hydrodynamic simulation, this center is having a strong impact on the design of new particle accelerators.

In FY 2006, ASCR is recompeting 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.

Scientific Facilities Utilization

The ASCR program's FY 2007 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 2,000 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 as described in the HECRTF report. The proposed funding will allow the high performance resources at the LCFs to be upgraded to a peak capability of 150 Teraflops in FY 2007.

	FY 2005	FY 2006 Estimate	FY 2007 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%

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 2007, this program will support approximately 800 graduate students and post doctoral investigators, of which 500 will be supported at SC user facilities.

ASCR will continue the Computational Science Graduate Fellowship Program with the successful appointment of 15 new students to support the next generation of leaders in computational science.

	FY 2005	FY 2006 Estimate	FY 2007 Estimate
# University Grants	140	135	150
Average Size	$197,000	$197,000	$197,000
# Laboratory Groups	165	155	165
# Graduate Students (FTEs)	354	350	375
# Permanent Ph.D.s (FTEs)	675	625	670

Mathematical, Information, and Computational Sciences

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Mathematical, Information, and Computational Sciences			
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	108,105	105,275	117,122
High Performance Computing and Network Facilities and Testbeds	118,075	123,116	193,030
SBIR/STTR	—	6,293	8,502
Total, Mathematical, Information, and Computational Sciences	226,180	234,684	318,654

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, answering critical questions that range from the function of living cells to the power of fusion energy.

Benefits

MICS supports ASCR's contribution to DOE's mission to provide world-class scientific research capacity 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. The science of the future demands that we advance beyond our current computational abilities. Accordingly, we must address the following questions:

- What new mathematics are required to 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 for SC?
- What operating systems, data management, analysis, model development, and other tools are required to make effective use of future-generation supercomputers?

- Is it possible to overcome the geographical distances that often hinder science by making 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 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

Discussions of the extent to which the requirements of the Office of Science exceed current capabilities and capacity can be found in a number of reports including: "Federal Plan for High-End Computing, Report of the High-End Computing Revitalization Task Force (HECRTF)" May 10, 2004, Appendices A-1, A-2, and A-3, (http://www.sc.doe.gov/ascr/hecrtfrpt.pdf); "A Science-Based Case for Large-Scale Simulation," Volume 1, July 30, 2003, (http://www.sc.doe.gov/ascr/Scalesreptvol1.pdf); "Theory and Modeling in Nanoscience, Report of the May 10-11, 2002 Workshop conducted by the Basic Energy Sciences and Advanced Scientific Computing Advisory Committees to SC, Dept. of Energy," (http://www.sc.doe.gov/ascr/TMN_rpt.pdf); "Integrated Simulation and Optimization of Magnetic Fusion Systems, Report of the FESAC Panel," November 2, 2002, (http://www.ofes.fusion.doe.gov/News/FSP_report_Dec9.pdf); and "High-Performance Networks for High-Impact Science, Report of the High-Performance Network Planning Workshop conducted August 13-15, 2002," (http://www.sc.doe.gov/ascr/high-performance_networks.pdf). Furthermore, the algorithms and software tools, libraries, and environments needed to accelerate scientific discovery through modeling and simulation are beyond the realm of commercial interest. To establish and maintain DOE's modeling and simulation leadership in scientific areas that are important to its mission, the MICS subprogram employs a broad, but integrated, research strategy. The MICS subprogram's basic research portfolio in applied mathematics and computer science provides the foundation for enabling research activities, which includes efforts to advance networking 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. Seventeen awards were made in FY 2002, twelve awards in FY 2003, sixteen in FY 2004, and twelve in FY 2005. Additional awards will be made in FY 2006 for this activity, pending the outcome of review of applications. 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 2005 Accomplishments

- Middleware collaboratory projects such as the Storage Resource Management project are providing the technology needed to manage the rapidly growing distributed data volumes produced as a result of faster and larger computational facilities. Over the past year, Storage Resource Manager software (SRMs) has been deployed in multiple High Energy Physics experiments as part of the Particle Physics Data Grid (PPDG) project, the Earth Science Grid (ESG), and the SciDAC Scientific Data Management Integrated Software Infrastructure Center (ISIC). SRMs are used by facilities such as BNL, NERSC, Fermilab, National Center for Atmospheric Research (NCAR) and ORNL for remote file access and intensive data movement between storage systems at different facilities. For example, SRMs have been setup to automate the movement of approximately 10,000 files per month (1 gigabyte each) between BNL and NERSC. Additionally sustained transfer rates between 40 and 60 megabytes per second have been achieved using SRM-to-SRM managed transfers from Castor at CERN to Fermilab's tape system. The benefit of using an SRM for these tasks is that error rates are reduced and human intervention is essentially eliminated.
- Energy Sciences Network (ESnet) is implementing a new architecture that is a core ring with interconnected metropolitan area networks (MANs). ESnet's current architecture consists of a national core network connecting six hubs with individual sites connected to the hubs in a single circuit, in spoke-like fashion. For reasons of both reliability and bandwidth, this architecture is insufficient to meet future demands. The new architecture is designed to meet the increasing demand for network bandwidth and advanced network services as next-generation scientific instruments and supercomputers come on line. The first MAN has been completed in the San Francisco Bay Area. It provides dual connectivity at 20 gigabits per second—which is from 10 to 50 times the previous site bandwidths, depending on the site using the ring—while reducing the overall cost. It connects six DOE sites—Stanford Linear Accelerator (SLAC), Lawrence Berkeley National Laboratory (LBNL), the Joint Genome Institute (JGI), the National Energy Research Scientific Computing Center (NERSC), Lawrence Livermore National Laboratory (LLNL) and Sandia National Laboratory (SNL) at Livermore. 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.
- UltraScienceNet Network (USNET) Testbed is a 20 gigabit per second highly reconfigurable optical network testbed developed to design and test advanced optical network technologies such as petabyte-scale data transfers, remote computational steering, collaborative high-end visualizations, and tele-instrumentation. A full deployment of USNET backbone was completed in August 2005. In the current configuration, it provides on-demand end-to-end guaranteed circuits with capacities ranging from 50 megabits per second to 20 gigabits per second within minutes of setup. Such

capability is in stark contrast with the Internet where the shared connections are statically provisioned and, as a result, the bandwidth is neither guaranteed nor stable. During the past year, USNET has enabled researchers at FNAL to develop and test advanced data transfer networking technologies capable of achieving data rates 15 times faster than with production ESnet networks and thousands of times faster than with traditional Internet connections. This achievement is very significant because it facilitates the efficient distribution of the high energy LHC data distribution between tier-1 and tier-2 centers. Upon maturation, the advanced networking technologies developed in USNET will be put into production in ESnet.

- Secure Group Collaborations – The SciDAC project "Security and Policy for Group Collaboration" has produced authentication and authorization algorithms and software that have been adopted by major distributed science projects. These projects have in turn profited from the availability of high-quality secure authentication and authorization mechanisms to achieve significant advances in distributed science. For example, the DOE Earth System Grid data portal has used Grid Security Infrastructure (GSI) mechanisms to register over one thousand climate researchers as users during the past year. These users have downloaded tens of terabytes of data from ESG sites and produced 250 publications from International Panel on Climate Change (IPCC) data alone. Thousands of scientists now access remote data and computational services on grid infrastructure securely thanks to Grid Security Infrastructure
- Performance Tools, Modeling and Optimization: Computer science researchers significantly enhanced the performance of several SciDAC applications, including,
  - a three-fold improvement of the fusion Gyrolcinetic Simulation model (GS2) on the IBM SP,
  - a two-fold improvement in the Community Atmospheric Model (CAM) on the Cray X1,
  - a 50% improvement in the Omega3P accelerator design code on an Opteron cluster.
- Using software components from NWChem, MPCQ, Tao Solver, Global Arrays, and PETSc, computer scientists and chemists have successfully performed quantum chemistry simulations obtaining a reduction in times up to 43% compared to the standalone chemistry packages.
- A novel, adaptive infrastructure for low-overhead monitoring for parallel applications on large-scale systems greatly reduces the volume of tracing data produced, and allows the user to specify constraints on the confidence and accuracy of monitoring. The Tuning and Analysis Utilities (TAU) parallel performance system is delivering state-of-the-art technology for performance instrumentation, measurement, and analysis of large-scale parallel computers to help application developers be more productive in achieving their optimization goals. The project is making important advances in application-specific performance evaluation, scalable performance tools, multi-experiment performance data management, and performance data mining. TAU has been ported to the IBM BG/L, Cray RedStorm, Cray XT3, and SGI Columbia systems, and TAU is used for performance analysis of important DOE production and research codes, including Flash, ESMF, KULL, VTF, Uintah, and S3D.
- Using lightweight one-sided communication in the Unified Parallel C (UPC) language, researchers demonstrated performance that was nearly double that of the standard NAS benchmark implementation in Fortran and MPI on an Itanium/Quadrics cluster and an Opteron/Infiniband cluster. These results were obtained using the Berkeley Open Source UPC compiler, and the UPC

code outperformed the MPI code on every platform and problem size tested. One of the evaluated benchmarks where performance doubled was a Fast Fourier Transform in 3D, a computation that is critical in climate modeling, fusion modeling, and many other SC applications.

- Researchers have developed an open-source compiler for Co-array Fortran (CAF), a model for parallel programming that consists of a small set of extensions to the Fortran 90 programming language. The prototype, multi-platform compiler was used in FY 2004 to develop efficient programs for a wide range of parallel architectures. Based on this work, in FY 2005 Co-arrays were officially adopted as part of the Fortran 2008 language standard. This is the first time the International Fortran Standards Committee has approved a parallel extension to the Fortran language.
- The Multi-Component-Multi-Data (MCMD) programming model was shown to be effective for improving scalability of real scientific applications on large processor counts. When combined with Global Arrays (GA), a computational scheme that supports three different levels of parallelism was implemented in the context of NWChem computational chemistry package. In particular, a factor of 10 reduction in the time needed to complete the numerical Hessian calculation was observed. This approach, is expected to be critical for running complex scientific applications on future massively parallel systems.
- The Scalable Linear Solvers project at LLNL has applied its Adaptive Smoothed Aggregation (αSA) method to Quantum Chromodynamics (QCD, currently funded under SciDAC). The αSA method is the only method ever to exhibit scalable convergence behavior on a QCD application independent of physics and discretization parameters, and αSA was shown to be faster than existing methods even on today's relatively small simulations. There were several new solver developments this past year that could have a similar impact on DOE applications in the future. A new variant of the adaptive multigrid idea has been developed and shown to be robust for difficult PDEs with large near null-spaces such as Maxwell's Equations on unstructured grids. Also, based on the new sharp convergence theory, a more predictive form of compatible relaxation has been developed that is aimed at further improving the robustness of algebraic multigrid (AMG). The co-principal investigators were invited to give eight talks at prestigious conferences such as the European Multigrid Conference, and included a Topical Lecture on AMG at this year's Society for Industrial and Applied Mathematics (SIAM) Annual Meeting. Their paper on αSA was selected by the editors of SIAM Journal on Scientific Computing (SISC) to appear as a SIGEST article in SIAM Review. The SIGEST section of the *SIAM Review* highlights excellent papers of broad interest from SIAM's specialized journals, making SIAM readers aware of outstanding work whose content and roots span multiple areas.
- As part of the Terascale Simulation Tools and Technologies (TSTT) applied mathematics Integrated Software Infrastructure Center (ISIC), researchers have developed and deployed advanced meshing and discretization technology to SciDAC application researchers in a diverse array of application areas. For example, PNNL scientists are applying TSTT tools to DOE bioremediation problems using the Virtual Microbial Cell Simulator (VMCS). The VMCS is one example where TSTT meshing and discretization technologies are being used successfully to construct a computational biology application. The main concept is to leverage this technology to provide a general biological application tool by providing common interfaces and interoperability among a set of computational biology tools.

- Argonne researchers have developed the Library for Automated Deduction Research (LADR), an evolving set of tools for constructing software for various automated deduction tasks. LADR greatly simplifies the task of building special-purpose systems for testing new theories and ideas in automated deduction—for example, programs that combine proof search with counterexample search and programs that automate the human-computer iterative processes typically used for difficult conjectures. Two production-quality programs have already been built with LADR. Prover9 searches for proofs of statements in first-order logic, and Mace4 searches for counter examples.
- Researchers at Argonne National Laboratory are providing a new modeling and solution paradigm for the design of efficient electricity markets. In a pilot project, they have used Stackelberg games to model the interactions between the producers and consumers in the Pennsylvania-New Jersey-Maryland electricity market and to investigate the implications of various delivery scenarios. The computational experience obtained with Argonne's large scale nonlinear optimization solvers will be useful to policy makers interested in simulating the complicated interactions among producers in imperfectly competitive markets. Future research will extend this modeling paradigm to games with more complex structure that will allow competition between two or more dominant producers in deregulated electricity markets.
- Argonne's Portable, Extensible Toolkit for Scientific Computing (PETSc) project develops scalable numerical solvers and software that support high-performance simulations based on partial differential equations (PDE). The parallel computing infrastructure and scalable numerical solvers in PETSc enable scientists and engineers to focus on the science, thus, reducing implementation costs. For example, DOE applications from Fusion Energy to Geosciences have taken advantage of PETSc's unique structure. In particular, researchers in computational fusion have employed PETSc both in gyrokinetic simulations and in two plasma simulation codes—one using spectral methods, the other finite element methods. Fusion is a major potential major alternative energy source, and the plasma production efforts of the International Thermonuclear Experimental Reactor (ITER), planned around the year 2014, will require extremely accurate simulation.
- Sandia researchers have developed two new linear solver algorithms, S-LSC and NSA, which will improve the performance of many fluid flow simulations central to the advanced modeling performed at the national laboratories. Among the applications that currently use these solvers are chemical vapor deposition computations for semiconductor and Microelectromechanical Machines (MEMS) processing, aerodynamics calculations to determining flight characteristics, and combustion simulations to understand pool fires and validate weapon systems. Some of these simulations have been performed on equation sets with over 100 million unknowns on thousands of processors. These increased capabilities lead to more detailed and physically realistic studies over larger ranges of physical and temporal scales.

FY 2005 Awards

- R&D 100 Award to Argonne National Laboratory (ANL) Team—Every year, R&D Magazine recognizes the world's top 100 scientific and technological advances with awards for innovations showing the most significant commercial potential. The Computer Science project "MPICH2" received an R&D 100 award for the year 2005. MPICH2 is a high-performance, portable implementation of community standards for the message-passing model of parallel computation. It enables scientists to write parallel programs that run efficiently on all major computers systems.

Companies such as Pratt and Whitney are using MPICH2 to design aircraft engines and the software is widely used in scientific applications.

- Innovative and Novel Computational Impact on Theory and Experiment (INCITE) Program—Some of the most significant work done at NERSC in 2005 was made possible by the INCITE Program, which supports a small number of computationally intensive large-scale research projects that are expected to make high-impact scientific advances through the use of a substantial allocation of computer time and data storage at the NERSC Center. In December 2004, SC selected three computational science projects to receive a total of 6.5 million hours of supercomputing time at the NERSC Center—10% of the total computing time available in FY 2005 on NERSC's Seaborg system. One of the INCITE projects, "Direct Numerical Simulation of Turbulent Nonpremixed Combustion," performed detailed three-dimensional combustion simulations of flames in which fuel and oxygen are not premixed. The results of their simulations will provide insight into reducing pollutants and increasing efficiency in combustion devices.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	**108,105**	**105,275**	**117,122**
▪ **Applied Mathematics**..	**29,577**	**29,354**	**29,495**

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. This final area represents our most recent effort at focusing on those mission-related applications which span wide ranges of interacting length- and time-scales.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

The FY 2007 budget increases the Computational Sciences Graduate Fellowship activity by $500,000 to $4,000,000. The FY 2007 budget also includes $8,500,000 for the Atomic to Macroscopic Mathematics effort, the same as in FY 2006.

	FY 2005	FY 2006	FY 2007
▪ **Computer Science**	**21,590**	**24,271**	**23,863**

This activity supports research in computer science to enable computational scientists to effectively utilize high-performance 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 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 data analysis and for circumstances where key resources and users are geographically distributed. Research areas include: tools to monitor the performance of scientific applications and enable users to improve performance and get scientific results faster; new programming models to simplify application code development; advanced techniques for visualizing very large-scale scientific data; and efforts to improve 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 NITR&D 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 (HEC URA), an outgrowth of the HECRTF. These activities will be modestly increased 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.

	FY 2005	FY 2006	FY 2007
▪ **Computational Partnerships**..	**35,769**	**38,052**	**50,000**

This activity supports the amalgam of those activities previously titled "Advanced Computing Software Tools" and "Scientific Applications Partnerships." 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 2007, this activity will support the Integrated Software Infrastructure Centers (ISICs) SciDAC activities, that were competitively selected in FY 2006. The ISICs funded under this activity will focus on important computational infrastructure problems such as: structured and unstructured mesh generation for large simulations and high performance tools for solving partial differential equations on parallel computers; tools for analyzing the performance of scientific simulation software that uses thousands of processors; the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives; software for managing computers with thousands of processors; and software component technology to enable rapid development of efficient, portable, high performance parallel simulation software.

The ISICs are a fundamental component in DOE's SciDAC strategy. The ISICs are responsible for the entire lifecycle of the software that they develop. These software tools must be reliable, understandable, and well documented. Also, the scientific user community needs these tools to be maintained, bug-free, and upgraded as necessary. Since software tools for high performance scientific simulations have no commercial market, the ISICs provide the only means for developing and deploying these tools to the scientific community.

The scientific applications partnerships part of this activity, formerly titled Scientific Application Pilot Projects, supports collaborative research with computational scientists in other disciplines to apply the computational techniques and tools developed by other MICS activities 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. The FY 2007 funding for this activity will allow the continuation of the multidisciplinary partnerships that were competitively selected in FY 2006. These projects are part of the SciDAC activity and are coupled to the ISICs. Areas under investigation include design of particle accelerators with the High Energy Physics (HEP) and Nuclear Physics (NP) programs, plasma turbulence in tokamaks with the Fusion Energy Sciences (FES) program, global climate change with the Biological and Environmental Research (BER) program, and combustion chemistry with the Basic Energy Sciences (BES) program. This activity directly supports SC Strategic Plan strategy 6.2.

The FY 2007 request includes funds to continue the partnerships with the BER Genomics: GTL program, the BES program in nanoscale science, and the FES program for the Fusion Simulation Project (FSP).

The FY 2007 request also includes $7,000,000 to continue the competitively selected SciDAC institutes at universities which can become centers of excellence in high end computational science in areas that are critical to DOE missions.

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

Finally, in FY 2007, this activity, as a part of the enhanced SciDAC effort, will begin a new investment in applied math and computer science to develop leadership class computing simulations for petascale computers in areas such as core collapse supernovae, molecular imaging of catalysis, combustion, tokamak experiments and the associated plasma physics, and expanding applied math and computer science in support of ultrafast science, lattice QCD, and simulation of nuclear reactions in collaboration with NNSA. This increment in SciDAC will enable the development of a suite of scientific software and science applications that can fully take advantage of petascale computers and build on SciDAC's initial success in enabling scientists to use those computers as tools for scientific discovery. This increment will enable SciDAC teams to prepare for 250 teraflop class computers in collaboration with applied mathematicians and computer scientists including focused efforts to transition early results from the basic research effort in Atomic to Macroscopic mathematics into multiscale algorithms in petascale scientific computing applications. This strategy for development of petascale applications to use petascale computers is critical for making further contributions to DOE science areas through modeling and simulation success.

- **Distributed Network Environment Research**.......................... **21,169** **13,598** **13,764**

This activity supported the integration of activities previously described under the titles: "Network Research," "Collaboratory Tools," and "Collaboratory Pilots." This integrated activity builds on results of fundamental research in computer science and networking to develop an integrated set of software tools and services to support distributed scientific collaborations and provide end-to-end network performance well beyond the levels that can be achieved today. For the past two decades the Office of Science (SC), and the worldwide scientific community, have benefited substantially from advances associated with the development and the building of the Internet. This has enabled roughly a doubling in bandwidth every two years with no increase in cost. However, the demands of today's facilities, which generate millions of gigabytes per year of data, now outstrip the capabilities of the Internet design. 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 an opportunity to exploit these technologies to provide scientific data where it is needed at speeds commensurate with the new data volumes.

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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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	**118,075**	**123,116**	**193,030**
▪ **High Performance Computing Facilities and Testbeds**	**99,496**	**104,150**	**170,294**

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 Class Computers (LCCs) 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 Center for Computational Sciences (CCS). Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware are also supported. FY 2007 capital equipment requirements for these types of capital equipment are increased from FY 2006.

• **High Performance Production Computing**	**37,868**	**37,489**	**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 2,000 users working on about 700 projects. 35% of users are university based, 61% are in National Laboratories, 3% are in industry, and 1% are in other government laboratories. FY 2007 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. 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, in FY 2006, a procurement is planned for the next generation of high performance resources at NERSC to be delivered in early FY 2007. The resultant NERSC-5 peak capacity is expected to be 100–150 teraflops by the end of FY 2007. These computational resources are integrated by a common high performance file storage system that enables users to easily use all the resources. The FY 2006 oversubscription at NERSC is about a factor of 6-8. In FY 2007, we will increase the capacity by about a factor of 6.

NERSC plays 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.

• **Leadership Computing Facilities (LCF)**	**48,600**	**53,702**	**102,504**

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. The success of this effort is built on

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

the enhancements to the research and evaluation prototype and computer science research activities described elsewhere.

▸ **Leadership Computing Facility at ORNL**	**48,600**	**53,702**	**80,000**

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 provide world leading high performance sustained capability to researchers on a peer-reviewed basis. The LCF will upgrade computers acquired in FY 2004 and FY 2005 to provide more than 250 teraflops peak capability by the end of FY 2007. These advancements will enable scientific advancements such as simulations of diesel combustion including realistic diesel fuel chemistry to minimize the processes that generate NO_x and soot, 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.

▸ **Leadership Computing Facility at ANL**	**—**	**—**	**22,504**

In FY 2007, further diversity with the LCF resources will be 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. This capability will accelerate scientific understanding in areas that include materials science, catalysis, protein/DNA complexes, and advanced designs of nuclear reactors. The IBM Blue Gene architecture is expected to deliver significantly greater performance per dollar for this class of applications than the computing at ORNL.

• **Research and Evaluation Prototypes**	**13,028**	**12,959**	**13,000**

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.

▪ **High Performance Network Facilities and Testbeds**..............	**18,579**	**18,966**	**22,736**

This activity supports SC strategy 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) that provide high bandwidth access to the ESnet backbone. The ESnet project/investment supports the agency's mission and strategic goals and objectives by providing DOE with interoperable, effective, and reliable communications infrastructure and leading-edge network services. ESnet supplies the DOE science community with capabilities not available through commercial networks or commercial Internet Service Providers. 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. ESnet provides the communications fabric that interconnects geographically distributed research facilities and large-scale scientific collaborations. ESnet supplies the critical infrastructure that links DOE researchers worldwide and forms the basis for advanced experimental research in networking, collaboratory tools, and distributed data-intensive scientific applications testbeds such as the national collaboratory pilot projects. This activity directly supports SC Strategic Plan strategy 6.4. ESnet provides network services through contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM), Synchronous Optical Networks (SONET) and Dense Wave Division Multiplexing (DWDM). ESnet interfaces its network fabric through peering arrangements to other Federal, education, and commercial networks, international research network connections, and the University Corporation for Advanced Internet Development (UCAID) Abilene network that provides high performance connections to many research universities. The MANs, which are developed by regional consortia of laboratories and other research institutions build on local knowledge of installed fiber optical infrastructure to provide an underlying DWDM fabric over which ESnet can manage high bandwidth end-to-end services.

In FY 2007, SC Networks will be upgraded dual backbone rings at 20 gigabits per second with fault tolerant connections of at least 10 gigabits per second to most major SC laboratories and higher bandwidth connections to selected laboratories to manage the increased data flows from petascale computers and the experimental facilities that are critical to the Nation's future. At this funding level the management of network facilities for SC will fully implement the transition to a partnership of high performance, fault tolerant backbone networks, which are entirely funded by ESnet, and regional or metropolitan area networks, where management responsibility is shared between ESnet and the laboratories in the region. ESnet's expertise in routing, cybersecurity, and public key infrastructure will have the maximum benefit for SC through an integrated management strategy. Connectivity to universities will be achieved through close partnerships with Internet2 and its networks. This increment 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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR)	**—**	**6,293**	**8,502**

In FY 2005, $5,614,000 and $674,000 were transferred to the SBIR and STTR programs respectively. The FY 2006 and FY 2007 amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs.

Total, Mathematical, Information, and Computational Sciences	**226,180**	**234,684**	**318,654**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	
▪ **Applied Mathematics**	
Increase in funding for Computational Sciences Graduate Fellowship activity to train next generation of leaders in computational science.	+141
▪ **Computer Science**	
Modest decrease in support for Computer Science research due to completion of several small research efforts.	-408
▪ **Computational Partnerships**	
Increase in partnership activities resulting from recompetition of SciDAC activities and initiation of new university based competition for SciDAC Institutes which can become centers of excellence in scientific areas critical to the missions of DOE and enhancements to SciDAC to develop leadership class computing simulations for petascale computers. This increment in SciDAC will enable the development of a suite of scientific software and science applications that can fully take advantage of petascale computers and build on SciDAC's initial success in enabling scientists to use terascale computers as tools for scientific discovery	+11,948
▪ **Distributed Network Environment Research**	
Increase in support for Distributed Network Environment Research to enable support of one additional peer reviewed research project.	+166
Total Funding Change, Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	**+11,847**

	FY 2007 vs. FY 2006 ($000)
High Performance Computing and Network Facilities and Testbeds	
▪ **High Performance Computing Facilities and Testbeds**	
• **High Performance Production Computing**	
Requested funding for high performance production computing at NERSC will increase its peak capacity (NERSC-5) to 100-150 teraflop.	+17,301
• **Leadership Computing Facilities (LCF)**	
▸ **Leadership Computing Facility at ORNL**	
The ORNL LCF will deliver 250 teraflops of capability in FY 2007.	+26,298
▸ **Leadership Computing Facility at ANL**	
The ANL LCF will deliver 100 teraflops of capability in FY 2007.	+22,504
Total Leadership Computing Facilities	**+48,802**
• **Research and Evaluation Prototypes**	
Research and Evaluation Prototypes will be continued at the FY 2006 level. These investments in Research and Evaluation Prototypes help prepare scientists for petascale computing and reduce the risks associated with future ASCR computer acquisitions.	+41
Total High Performance Computing Facilities and Testbeds	**+66,144**
▪ **High Performance Network Facilities and Testbeds**	
Increases in funding to enable ESnet to meet current and near-term future network needs of SC. This increment builds on the tools and knowledge developed by the Distributed Network Environment research effort to enable SC to realize the promise of optical networks for DOE missions.	+3,770
Total Funding Change, High Performance Computing and Network Facilities and Testbeds	**+69,914**
SBIR/STTR	
Increase in SBIR/STTR due to increase in operating expenses.	+2,209
Total Funding Change, Mathematical, Information, and Computational Sciences	**+83,970**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Capital Equipment	9,942	9,964	15,000

Biological and Environmental Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Biological and Environmental Research					
Life Sciences	198,643	204,035	-2,040[a]	201,995	264,158
Climate Change Research	135,535	142,959	-1,430[a]	141,529	134,909
Environmental Remediation	100,575	94,694	-950[a]	93,744	97,196
Medical Applications and Measurement Science	121,924	144,000	-1,437[a]	142,563	14,000
Subtotal, Biological and Environmental Research	556,677	585,688	-5,857	579,831	510,263
Construction	9,920	—	—	—	—
Total, Biological and Environmental Research	566,597[b]	585,688	-5,857	579,831	510,263

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"
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 biomedical 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 vital national 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 world-class scientific research capacity and advancing scientific knowledge by supporting world-class, peer-reviewed scientific results in biology and environmental science whose results are published in the scientific literature. Basic biological and environmental research has broad impacts on our health, our environment, and our energy future. An ability to predict long-range and regional climate enables effective planning for future needs in energy, agriculture, and land and water use. Biotechnology solutions are possible for DOE energy, environmental, and national security challenges by understanding complex biological systems and developing computational tools to model and predict their behavior. Understanding the global carbon cycle and the associated role and capabilities of microbes and plants

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.
[b] Total is reduced by $4,678,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $13,674,000, which was transferred to the SBIR program; and $1,641,000, which was transferred to the STTR program.

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. Both normal and abnormal health—from normal human development to cancer to brain function—can be understood and improved using radiotracers, advanced imaging instruments, and novel biomedical devices. 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 Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the mission) plus seven general goals that tie to the strategic goals. The BER program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.
The BER program has one program goal which contributes to General Goal 5 in the "goal cascade":
Program Goal 05.21.00.00: 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 Program Goal 05.21.00.00 (Harness the Power of Our Living World)
BER contributes to Program Goal 05.21.00.00 by advancing fundamental research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical applications. BER supports leading research programs that provide world-class, merit-reviewed research results. 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 will 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 of global climate change and our ability to predict climate over decades to centuries will enable us to develop science-based solutions to minimize the impacts of climate change and to better plan for our Nation's future energy needs. 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. Understanding the fate and transport of environmental contaminants will lead the way to discovering innovative approaches for cleaning up the environment.

BER research leads to the development of advanced medical imaging technology, including radiopharmaceuticals for imaging to be used for diagnosis and treatment of disease. BER research also advances the development of a broad range of intelligent biomimetic electronics that can both sense and correctly stimulate the nervous system, e.g., an artificial retina that will enable the blind to see, and that will lead to development of intelligent micro machines that interface with the brain and spinal cord to overcome disabilities. This research capitalizes on the national laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health, and on their sophisticated instrumentation (neutron and light sources, mass spectroscopy, and high field magnets), lasers and supercomputers. This research is coordinated with other complementary Federal programs.

In addition, BER plans, constructs, and operates reliable, world-class 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 operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) (including the Molecular Sciences Computing Facility) where research activities underpin long-term environmental remediation and other DOE missions in energy and national security; the Production Genomics Facility (PGF); the Laboratory for Comparative and Functional Genomics ("Mouse House"); and the climate change research facilities – the Atmospheric Radiation Measurement (ARM) and the Free-Air Carbon Dioxide Enrichment (FACE) facilities.

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:** Characterize the multi-protein complexes (or the lack thereof) involving a scientifically significant fraction of a microbe's proteins. Develop computational models to direct the use and design of microbial communities to clean up waste, sequester carbon, or produce hydrogen.
- **Climate Change Research:** Deliver improved climate data and models for policy makers to determine safe levels of greenhouse gases for the earth's system. By 2013, substantially reduce differences between observed temperature and model simulations at subcontinental scales using several decades of recent data.
- **Environmental Remediation:** By 2015, provide sufficient scientific understanding to allow a significant fraction of DOE sites to incorporate coupled biological, chemical and physical processes for 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.21.00.00 Harness the Power of Our Living World (Biological and Environmental Research).......	566,597	579,831	510,263

[a] This indicator is not a PART measure.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 05.21.00.00 (Harness the Power of Our Living World)					
Life Sciences					
Increase the rate of DNA sequencing; Produce at least 12.7 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	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.	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.
Climate Change Research					
Improve climate models: Released a new coupled climate model with a horizontal resolution of 2.8 degrees (longitude and latitude) in the atmosphere and 0.7 degrees in the ocean and sea ice components, compared to the previous version with a resolution of 2.8 degrees in the atmosphere and 2.0 degrees in the ocean. Executed an 800-year equilibrium climate simulation with the new model. [Met Goal]	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	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.

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Environmental Remediation					
Determine scalability of laboratory results in field environments: Using genomic sequencing data of key bioremediation microbes, such as Geobacter, Deinococcus, and Shewanella, determined that common soil microbes produce organic compounds that interact with radionuclides, such as plutonium, providing the molecular understanding for the detection and transformation of radionuclides in subsurface environments. [Met Goal]	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.	Implement a field-oriented, integrated experimental research program to quantify coupled processes that control reactive transport of at least one key DOE contaminant.
Medical Applications and Measurement Science[a]					
Advance blind patient sight: Developed technology to micromachine new flexible biocompatible material to be used as a platform for multi-electrode array artificial retina. [Met Goal]	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. [Met Goal]	Advance blind patient sight: Begin testing of prototypes for 256 microelectrode array artificial retina.	Advanced blind patient sight: complete design and construction of final 256 electrode array. Begin in vitro testing and non-stimulating testing in animals.
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 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.	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.

[a] This is not a PART measure.

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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 development of a new research infrastructure needed to understand fundamental biological principles underlying the function and control of biological systems, the heart of the Genomics: GTL program. 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 critical problems in energy and environmental cleanup.

Our ability to predict climate on global and regional scales and to develop strategies for the removal of excess carbon dioxide, suspected to adversely impact global climate, from the atmosphere will depend on the continued development of novel research tools and a close integration of experimental 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 Environmental Molecular Sciences Laboratory (EMSL), the Production Genomics facility, the Laboratory for Functional and Comparative Genomics, Atmospheric Radiation Measurement (ARM) facilities, and Free Air Carbon Dioxide Enrichment (FACE) 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 emerge in ways that 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.

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) Assessment

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 into the FY 2007 Budget Request and has taken or will take the necessary steps to continue to improve performance.

The Biological and Environmental Research (BER) Program last completed PART in support of the FY 2005 Budget Request. At that time, the program was rated as "Effective."

In the FY 2004 PART, OMB recommended that BER form Committees of Visitors (COVs) to review management of the BER research portfolio. The FY 2005 PART Summary Sheet Recommended that the Department develop an appropriate action plan in response to the findings and recommendations of the Committee of Visitors within 30 days of receipt of the report. Two BER COVs have been formed. The first COV was charged on July 23, 2003, to look at the Climate Change Research Division. This COV met on March 1–3, 2004, and reported to the Biological and Environmental Research Advisory Committee (BERAC) in November 2004. The Department responded to this report in December 2004. The Second COV was charged on April 21, 2004, to look at the Environmental Remediation Sciences Division. This COV met on October 5–7, 2004, and reported to BERAC in November 2004. The Department responded to this report in December 2004. In the FY 2006 PART Summary Sheet, OMB found the timely BER responses to both reports to be thoughtful and thorough.

For the FY 2004 PART, BER worked with OMB to develop more meaningful long-term performance goals for the program. BER then worked with BERAC to ensure that these measures were ambitious yet realistic and to define for each what would be required for the program to be "successful" and "minimally effective". The FY 2005 PART Summary Sheet Recommended that the Department work with its advisory committee to develop research milestones against which future outside panels may judge interim progress toward achieving the long-term goals of the program. In the FY 2006 PART Summary Sheet, OMB found that the BER program's research milestones—as expressed in the new DOE program plans—were produced and reflect the strategic goals of the program, and the BER advisory committee as a whole has provided formal comments on the milestones. Panels will be charged to review progress toward the BER long-term goals using the criteria developed by BERAC and will report to the program in FY 2006.

For the FY 2007 Budget, OMB has developed PARTWeb—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the http://ExpectMore.gov website and will improve public access to PART assessments and follow up actions. For 2006 there are three actions for Biological and Environmental Research.

- Engaging the National Academies in an independent assessment of the scientific basis and business case for the program's microbial genomics research efforts.
- Implementing the recommendations of past external panel reviews of the program's research portfolio and management practices.

- Reviewing operations of user facilities, and improving discrimination in identifying open user facilities versus collaborative research facilities.

In response, BER has engaged the National Academies to review Genomics: GTL and expects a report by February 12, 2006. BER will also continue to publish responses to the COV's findings and will track improvements at http://www.sc.doe.gov/measures/FY06.html. The Biological and Environmental Research Advisory Committee has been reviewing the user facilities. BER will act on the results of these reviews to improve facility management.

Overview

BER supports fundamental 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 Biological and Environmental Research Advisory Committee (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, including the sequencing of the human genome, will bring revolutionary and unconventional solutions to some of our most pressing and expensive challenges in health, energy, the environment, and national security.

We will understand how living organisms interact with and respond to their environments so well that we will be able to use biology to produce clean energy, remove excess carbon dioxide from the atmosphere, and help clean up the environment. Our understanding of global climate change and our ability to accurately predict climate over decades to centuries will enable us to develop science-based solutions to minimize the impacts of climate change and to better plan for our Nation's future energy needs. 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. Understanding the fate and transport of environmental contaminants will lead the way to discovering innovative approaches for cleaning up the environment. Both normal and abnormal health—from normal human development to cancer to brain function—can be understood and improved using radiotracers, advanced imaging instruments, and novel biomedical devices.

The Challenges

Understanding and predicting climate – Advanced climate models are needed to describe and predict the roles of oceans, the atmosphere, sea ice, and land masses on climate. So too, the role of clouds in controlling solar and terrestrial radiation onto and away from the Earth needs to be better understood since it is the largest uncertainty in climate prediction. Moreover, the impacts of excess carbon dioxide in the atmosphere from human sources, including energy use, on Earth's climate and ecosystems need to be determined and possible mitigation strategies developed.

A cleaner environment – Environmental sciences are undergoing a revolution, thanks in large part to the same molecular tools that have revolutionized biology in the last few decades—synchrotron radiation, advanced imaging and microscopy, and modern genomics. At the same time, the importance and roles of microbes in the environment are just beginning to be understood. How do microbes impact the geochemical cycles in the earth? How do they respond to perturbations, such as contamination? How do contaminants move through the subsurface? And how can we use nature's own biogeochemical 'tricks' to help us clean up contaminated sites in the DOE weapons complex and other places?

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

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

The Investment Plan

All BER 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 will 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) an improved ability to predict climate on global and regional scales; (3) development of strategies to remove excess carbon dioxide from the atmosphere; (4) new science-based strategies for the remediation, and long-term monitoring of the environment; and (5) the development of unique devices and technologies for the medical community that improve our Nation's health.

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 actively seeks external input using a variety of advisory bodies. BER regularly compares its programs to the scientific priorities recommended by the BERAC and by the standing committees created by the Office of Science and Technology Policy (OSTP). BER staff and BERAC both interact with and receive feedback from other programs and advisory committees across the Department including Advanced Scientific Computing Research; Basic Energy Sciences; Environmental Management; Energy Efficiency and Renewable Energy; Nuclear Energy, 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. BER is currently having its Genomics: GTL program, including the GTL Roadmap, reviewed by the National Academies of Science. 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. BER facility operations have also been reviewed by BERAC and by a 1999 OSTP interagency working group evaluating structural biology user facilities. In FY 2005, the Office of Science's Construction Management Support Division has reviewed BER's Environmental Molecular Sciences Laboratory. 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 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.

BER goes one step further in conducting program reviews. Panels of distinguished scientists are regularly charged with evaluating the quality of individual programs and with exploring ways of introducing new ideas and research performers from different scientific fields. This strategy is based on the conviction that the most important scientific advances of the new century will occur at the interfaces between scientific disciplines, such as biology and information science. The BER program is ideally positioned to facilitate and foster interactions between the physical sciences, the computational sciences, the environmental sciences, and the life sciences, and aggressively pursues every opportunity to nurture collaborations at the interfaces between these scientific domains.

Planning and Priority Setting

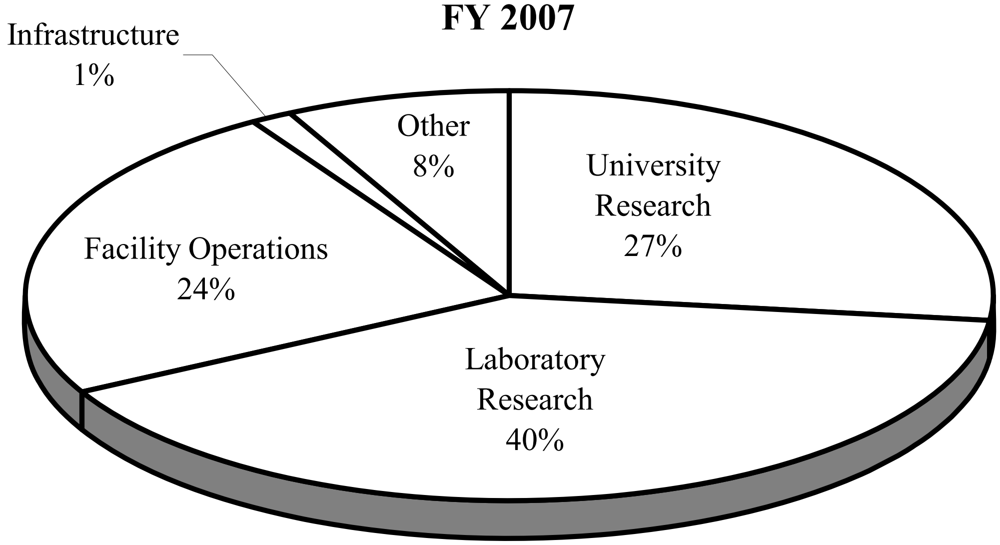
BER prides itself on supporting research and developing new research initiatives that lead the way across many fields of science and that effectively bring together many different disciplines, including biology, chemistry, engineering, computing, and the physical sciences. Merit reviews and user feedback are incorporated as BER anticipates and plans for the future needs of DOE research in the life and environmental sciences. This includes planning for future directions, opportunities, and initiatives within the BER research portfolio; maintaining the flexibility to quickly move into promising new areas; contributing to the health of the educational pipeline in critical subfields and disciplines; planning for upgrades at existing facilities to expand the research capabilities or operational capacity; ensuring the proper balance between facilities and research; and planning for future facilities necessary to advance the science in areas relevant to BER's mission with strong involvement of the research community.

BER planning and priority setting are also key BERAC activities and part of BER's interagency coordination. Individual BER program elements, e.g., human genome, low dose radiation research, Genomics: GTL, bioremediation research, global climate change, and medical applications 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 (27%); basic research at national laboratories (40%); and user facility support (24%). The remaining 9% 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 (8%)). Research at national laboratories also includes Unmanned Aerial Vehicles and other elements that represent a research infrastructure for the scientific community that includes both university and laboratory scientists. BER's user facilities include the infrastructure at synchrotron and neutron sources for structural biology and the environmental sciences, operation and equipment for the Environmental Molecular Sciences Laboratory (EMSL), support for high-throughput DNA sequencing at the Joint Genome Institute, Atmospheric Radiation Measurement Infrastructure, Free-Air CO_2 Enrichment (FACE) experimental facilities, and for the Laboratory for Cooperative and Functional Genomics ("Mouse House").

Biological and Environmental Research Budget Allocation FY 2007



Research

In FY 2007, the BER program will support fundamental 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 Research:*** University researchers play a critical role in the BER program, conducting fundamental research and developing the next generation of scientists for the nation's biological and environmental research efforts. BER will continue its commitment to and dependence on scientists at the Nation's universities. In general, BER-supported research at universities and research institutions are single investigator projects. Approximately half of BER basic research funding supports university-based activities directly and indirectly. University scientists are the major scientific users at BER facilities that include the ARM program, DNA sequencing, structural biology, FACE, EMSL, and the Laboratory for Comparative and Functional Genomics.

  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, FACE, 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 unique roles for the Department and the national and international scientific communities including:

- Manage research on microbes for energy and the environment, and work with the Advanced Scientific Computing Research program to develop the computational methods and capabilities needed to advance understanding of complex biological systems, predict their behavior, and use that information to address DOE needs;
- Provide the research infrastructure needed to (1) characterize the multi-protein complexes that result in microbial products and processes of use to DOE, and (2) determine the functional repertoire of complex microbial communities that can be used to address DOE needs;
- Provide world-class structural biology user facilities;

- Provide cutting edge technologies, facilities (including high-throughput community DNA sequencing capabilities), and resources, including animal models, for genomics research;
- Provide world-class scientific user facilities for environmental and climate change research;
- Provide world leadership in low dose radiation research;
- Provide world leadership in the understanding of how metal and radionuclide contaminants interact with the environment and how environments respond to their presence;
- Provide world leadership in ground-based measurement of clouds and atmospheric properties to resolve key uncertainties in climate change, through the ARM program;
- Develop advanced predictive capabilities using coupled climate models on the Nation's premier computers for decade-to-century long simulations of climate change;
- Support fundamental research on carbon sequestration to develop technologies that enhance the uptake of carbon in terrestrial and ocean ecosystems;
- Provide the scientific knowledge and enabling discoveries to reduce the risks and costs associated with the cleanup of the DOE weapons complex and provide a basis for similar mission needs related to energy, water, and the disposal and storage of waste;
- Provide world leadership in 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 Department are protected while advances in biomedical, environmental, nuclear, and other research lead to discoveries that benefit humanity.

Significant Program Shifts

- BER will focus research activities on higher priorities, especially GTL, in support of Departmental goals and objectives. Funding reductions are initiated in the Environmental Remediation Research and in the Climate Change Research Subprograms. High level waste (including waste in storage tanks), ocean sciences, and carbon sequestration research are terminated within these two subprograms.

Genomics: GTL Research

The FY 2007 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. This research will continue to more fully characterize the inventory of multi-protein molecular machines found in selected DOE-relevant microbes and higher organisms. It will determine the diverse biochemical capabilities of microbes and microbial communities, especially as they relate to potential biological solutions to DOE needs, found in populations of microbes isolated from DOE-relevant sites. GTL research will provide the scientific community with knowledge, resources, and tools that benefit large numbers of research projects with positive impacts on more scientists and students than are negatively impacted by the initial reduction.

Development of a global biotechnology based energy infrastructure requires a science base that will enable scientists to redesign specific proteins, biochemical pathways, and even entire plants or microbes. Biofuels could be produced using plants, microbes, or isolated enzymes. Understanding the biological mechanisms involved in these energy producing processes will allow scientists and technologists to design novel biofuel production strategies involving both cellular and cell free systems that might include defined communities of microbes and engineered nanostructures. Within the Genomics: GTL program, BER will develop the understanding needed to advance biotechnology-based strategies for biofuel production, focusing on biohydrogen and bioethanol.

Biological Production of Hydrogen–Some microorganisms produce hydrogen naturally, and biotechnologies based on these microbial systems will lead to the development of clean, renewable sources of hydrogen. Under certain conditions, green algae and a type of bacteria known as cyanobacteria can use energy from the sun to split water and generate hydrogen. This process, known as biophotolysis, has the potential to produce hydrogen on the scale necessary for meeting future energy demand. This approach to hydrogen production is promising because it uses water as a source of hydrogen—a clean, renewable, carbon-free (i.e., non-fossil fuel based), substrate available in virtually inexhaustible quantities. Another advantage of biophotolysis, compared to engineered systems that capture and use sunlight, is the more efficient conversion of solar energy to hydrogen. Using and improving microbial systems to directly produce hydrogen from water eliminates inefficiencies associated with hydrogen production from biomass, such as producing and harvesting the biomass itself. Theoretically, the maximum energetic efficiency for direct biophotolysis is 40% compared with a maximum of about 1% for hydrogen production from biomass (Critical Reviews in Microbiology 31, 19-31, 2005). Fundamental research will be supported to understand biophotolysis, and other processes, well enough that predictive models of hydrogenase (the enzyme that cleaves water to produce hydrogen) structure and function, 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, understanding how hydrogenases work, the inhibition of hydrogenase activity by oxygen, and genetic regulatory and biochemical processes that influence hydrogen production. This new knowledge will be used to engineer the ideal microbe to use in hydrogen bioreactors or the ideal enzyme-catalyst to use in bioinspired nanostructures for hydrogen production.

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 significantly larger portion of U.S. gasoline demand. A recent report ("Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply," available from Oak Ridge National Laboratory, Oak Ridge, TN 37831; ORNL/TM-2005/66) has projected that relatively modest changes in the use of farmlands and forests could produce more than 1.3 billion dry tons of biomass per year, enough to reduce current oil demand by at least one-third given conservative estimates of conversion efficiencies. 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 cell walls, primarily cellulose. 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. The long-term goal is to integrate the bioprocessing into a single step. Accomplishing this requires the development of genetically modified, multifunctional microbes or a stable mixed culture of microbes capable of carrying out all biologically mediated transformations needed for the complete conversion of biomass to ethanol. Research will be supported on a variety of enzymes and microbes that contribute (individually and together) to the conversion of cellulose to ethanol; analysis of enzymes to understand how they interact with and breakdown cellulose; a determination of the factors, such as temperature and different combinations of sugars, that influence biomass degradation or ethanol production; strategies for producing and maintaining stable mixed cultures of microbes; and improved capabilities for genetically engineering microbes that produce bioethanol. This research will lead to increased understanding of microbe-based production of cellulosic ethanol, increased production efficiencies, and reduced costs that will make cellulosic ethanol a cost-competitive alternative to gasoline in the coming decades.

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 2007 is $126,187,000.) 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 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 the economic costs and benefits of climate change and the different potential options for mitigation and adaptation to such change. The deliverables from this BER research will be highlighted by information useful to policy makers.

In FY 2007, 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 Cloud and Radiation Testbed 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; 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 (SciDAC)

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 are impossible 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 to parity with experiments 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.

In FY 2007, BER will continue to advance the science of climate modeling by coupling models of different components of the earth system related to climate and by significantly increasing the spatial resolution of global climate models. These SciDAC-enabled activities will allow climate scientists to gain unprecedented insights into potential effects of energy production and use on the global climate system.

BER will add a SciDAC component 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, such as mass spectrometry data. Environmental Remediation SciDAC will provide an opportunity for subsurface and computational scientists to develop and improve methods of simulating subsurface reactive transport processes on "discovery class" computers. 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.

Scientific Facilities Utilization

The BER request includes funds to maintain support of the Department's major scientific user facilities. BER has expanded the definition of a scientific user facility to include facilities such as 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 Production Genomics Facility; the Laboratory for Comparative and Functional Genomics ("Mouse House"); and the ARM and FACE 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

	FY 2005	FY 2006	FY 2007
	Actual	Estimated	
EMSL			
Optimal hours	4,365	4,365	4,365
Scheduled hours	4,365	4,365	4,365
Operation Time	95%	95%	>98%
Users[a]	1400	1600	1700

[a] EMSL users are both onsite and remote. Individual users are counted once per proposal in a reporting period regardless of the number of visits or accesses but individual scientists could be counted as more than one user if they are part of independently merit reviewed proposals.

	FY 2005	FY 2006	FY 2007
	Actual	Estimated	
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[a]	50	80	120
Laboratory for Comparative and Functional Genomics ("Mouse House")			
Optimal hours	3,536	3,536	3,536
Scheduled hours	3,536	3,536	3,536
Operation Time	>99%	>99%	>99%
Users[b]	20	20	20
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[c]	800	800	850
Free Air Carbon Dioxide Enrichment (FACE)			
Optimal hours	3,865	3,865	3,865
Scheduled hours	3,865	3,865	3,865
Operation Time[d]	>95%	>95%	>96%
Users	150	150	195

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 the capital equipment is held approximately at near the FY 2006 level.

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[a] 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.

[b] Users are both remote and onsite. A user is defined as a research group with a project that uses the facility. Each group is counted only once regardless of how many visits or individual staff in the group use the facility.

[c] ARM users are both onsite and remote. A user is an individual who accesses or uses equipment or computers 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.

[d] FACE users are both onsite and remote. Individuals are counted once per proposal in a reporting period regardless of the number of visits or accesses but individual scientists could be counted as more than one user if they are part of independently merit reviewed proposals. An onsite user who uses more than one FACE site is counted once for each of the sites used to carry out the research unless the research is to compare results between multiple FACE sites.

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 infrastructure. This ensures that the PNNL and ORISE infrastructures will continue to enable the Department's mission activities at these sites.

Workforce Development

Workforce development is an integral and essential element of the BER mission to help ensure a science-trained workforce, including researchers, engineers, science educators, and technicians. The research programs and projects at the National Laboratories, universities, and research institutes actively integrate undergraduate and graduate students and post-doctoral investigators into their work. This "hands-on" approach is essential for the development of the next generation of scientists, engineers, and science educators. Specific fellowship programs are also sponsored by BER to target emerging areas of need in global change research. About 1,400 graduate students and post-doctoral investigators will be supported at universities and at National Laboratories in FY 2007, 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 2007.

Office of Science user facilities are playing an increasingly important 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 2007. 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 is working with BES, and BER provides funding to each of the synchrotron light sources for environmental researchers. This funding provides user support for BER sponsored scientists as well as 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 and university 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, structural biology, low dose radiation research, climate change research, bioremediation research, medical imaging, and radiopharmaceutical development. Furthermore, university scientists work in close partnership with scientists at National Laboratories in many other BER programs including genomics, and carbon sequestration research.

	FY 2005	FY 2006 est.	FY 2007 est.
# University Grants..................	855	700	700
Average Size per year	$300,000	$250,000	$250,000
# Laboratory Projects................	400	375	350
# Permanent Ph.D.s[a] (FTEs).....	1,540	1,321	1,291
# Postdoctoral Associates[b] (FTEs)......................................	400	299	297
# Graduate Students[k] (FTEs)....	500	436	423
# Ph.D.s awarded[c].....................	125	100	105

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been 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.

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[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 2005	FY 2006	FY 2007
Life Sciences			
Structural Biology	21,859	15,084	15,300
Molecular and Cellular Biology	103,669	109,670	159,942
Human Genome	62,941	62,885	74,575
Health Effects	10,174	8,808	7,321
SBIR/STTR	—	5,548	7,020
Total, Life Sciences	198,643	201,995	264,158

Description

The mission of the Life Sciences subprogram is to foster fundamental research in the biological and life sciences that will provide new insights and advance knowledge to underpin the Department of Energy's mission needs. Biotechnology offers the promise of revolutionary solutions to energy and environmental challenges facing DOE and the Nation. Fundamental Life Sciences research will deliver a new knowledge base for cost effective cleanup of environmental contamination, design of new strategies for enhanced capture of atmospheric carbon dioxide, and increased bio-based sources of fuel or electricity. The program will 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 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 biochemical capabilities of complex microbial communities that could be used to produce clean energy, clean up or stabilize wastes *in situ*, or sequester excess atmospheric carbon dioxide. Resources are developed and made widely available for determining protein structures at DOE synchrotron, for high-throughput genetic studies using mice, and for high-throughput genomic DNA sequencing. New capabilities are developed in the Genomics: GTL program for understanding the structure, function, and regulation of multi-protein complexes from DOE-relevant organisms and of complex, DOE-relevant microbial communities – information needed to develop biotechnological solutions for DOE needs.

Supporting Information

BER Life Sciences supports research in the following 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 a better scientific basis for adequately protecting people from the adverse effects of ionizing radiation.
- 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 – from single microbes to communities of multiple microbial species. This information can be used to develop innovative biotechnology solutions for energy production, waste cleanup, and carbon management.

- A high-throughput DNA sequencing user resource to meet DNA sequencing needs of the scientific community.
- Resources, tools, and technologies to understand the function of human genes identified as part of the International Human Genome Project using the mouse.

Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This subprogram was reviewed as part of a BERAC review of the entire BER program in FY 2001 and by a BERAC Committee of Visitors (COV) in FY 2005. The next scheduled review of the Life Sciences subprogram by a BERAC COV will likely be in FY 2009.

FY 2005 Accomplishments

- Getting a Sense of Community: For the first time, both genomic and proteomic approaches have been used on a naturally occurring microbial community from an acid mine drainage site to characterize the "community genome" as well as the "community proteome" and promising insights into potential biotechnology strategies for remediation of toxic materials.
- Microbial Genome Clearinghouse—You May Have Already Won: DOE's Joint Genome Institute has developed a new clearinghouse (http://img.jgi.doe.gov/v1.0/main.cgi) that will help researchers analyze the deluge of DNA data on microorganisms. The site currently stores nearly 300 draft or completed genome sequences from archaea, bacteria, and other microbes, along with tools for sifting through the data. Besides basic information about the gene, its protein, and its function, visitors can summon diagrams illustrating which biochemical pathways the gene influences. Browsing tools make it easy to pinpoint similar genes in different organisms and compare them side by side.
- Spotlighting Cellular Processes: The ability to insert fiber-optic probes into living cells to watch cellular processes unfold has been developed. Biological probes, such as antibody molecules, are mounted on the tip of small fibers and pushed through a cell's outer membrane. When the probe encounters its target it triggers a detectable fluorescence signal. This system has been used to detect DNA damage from chemical carcinogen exposure and, for the first time, has enabled scientists to witness the onset of apoptosis, or programmed cell death, in real time. This exciting technology will now be adapted to monitor reactive oxygen species produced in live cells in response to low doses of ionizing radiation.
- Fixing Radiation Damage—It's When, Not What: The extreme radiation resistance of the microbe *Deinococcus radiodurans* has been shown to not be due to unusual or extra genes that less resistant bacteria lack, but rather that is due to regulatory alterations that permit them to use their repair mechanisms much more efficiently. This discovery may lead to the identification of ways to increase the radiation resistance of cells prior to radiation exposures.
- A Hypothetically Speaking, It's in the Genes: New approach for identifying "hypothetical genes" has been developed that combines experimental and computational analyses. Integrative approaches such as this offer valuable strategies for undertaking the enormous challenge of characterizing the rapidly growing number of "hypothetical" proteins that are found in each newly sequenced genome.
- Microbes Exchange Information to Clean Up Our Act: The genome of a microbe that can be used to clean up pollution by chlorinated solvents – a major category of groundwater contaminants that are

often left as byproducts of dry cleaning or industrial production has been determined. The newly determined DNA sequence provided evidence that the soil bacterium may have developed the metabolic capability to consume chlorinated solvents fairly recently, possibly by acquiring genes from a neighboring microbe in order to survive the increased prevalence of the pollutants. This proposed lateral gene transfer is part of a rapidly growing body of evidence that will dramatically change our understanding of distant and recent microbial evolution.

- Big Science Successes: From Sea to Mining See!: The work of BER-funded scientists was identified as two of the top science stories of 2004. Research on the Sargasso Sea, resulted in the discovery of more than a million new genes that had never been seen before including the startling result that a gene whose product had previously been thought of as a light receptor may be used by many marine bacteria to process carbon. Environmental genomics research focuses on a small microbial community inside an abandoned mine where the pH is extremely acidic. This research spotlights the value and potential of environmental genomics using advanced genome sequencing technologies to study the genomes of entire communities, research made possible by pioneering DOE investments in the genomic sequencing complex community DNA samples.
- Bringing Science Ethics to your Living Room: The TV documentary “Bloodlines: Technology Hits Home,” (http://www.pbs.org/bloodlines/) won the top broadcast award of the National Association of Science Writers (NASW), the top science journalism award in the U.S. The topic of Bloodlines is the ethical, legal, and societal challenges emerging from the Human Genome Project and some of the difficulties and dilemmas caused by the interaction of cutting edge science and the law. “Bloodlines” was originally funded by the Ethical, Legal, and Social Issues element of the BER Human Genome Program.
- Stretching a Visual Point with DNA: Optical mapping is a technology to directly image a “stretched-out” molecule of genomic DNA using the unique locations of restriction enzyme cut sites as orientation markers along the length of the DNA. This technique has now been used to directly compare single genomic DNA molecules from a series of different microbes to identify and annotate DNA alterations between bacterial strains represented by several species, including a microbe whose genome has not yet been sequenced. The results suggest that genomic rearrangements and chromosomal breakpoints of an unsequenced microbe can be readily identified and annotated against a previously sequenced strain using optical mapping. This will speed the analysis of microbial genomes by comparative genomics by using information from previously sequenced microbial species.
- Performance Art by Diatoms: Diatoms are simple single-celled algae, covered with elegant and often very beautiful casings sculpted from silica. They share biochemical features of both plants and animals and are related to the organisms that make up the well known White Cliffs of Dover in England. Scientists have taken a big step toward resolving the paradoxical nature of these odd microbes by sequencing the genome of the marine diatom *Thalassiosira pseudonana.* Analyses of these genes and the proteins they encode confirm that diatoms, in their evolutionary history, apparently acquired new genes by engulfing microbial neighbors including, possibly, genes that provided the diatom with all the machinery necessary for photosynthesis. Diatoms occupy vast swaths of ocean and fresh water, where they play a key role in the global carbon cycle. Diatom photosynthesis yields 19 billion tons of organic carbon, about 40% of the marine carbon produced each year, and thus represent one of nature’s key defenses against global warming. Progress in analyzing the diatom genome is also shedding light on how a diatom constructs its intricately patterned glass shell, progress that could benefit both materials and climate change scientists.

- Some Archaea Eat Their Dessert First: Scientists describe the use of genome based analyses of methane-oxidizing *Archaea* (evolutionarily ancient microorganisms) from deep-sea sediments to study the biological mechanisms controlling anaerobic methane oxidation. One current model suggests that relatives of methane-producing *Archaea* developed the capacity to consume methane to produce cellular carbon and energy. The new results show that nearly all of the genes typically associated with methane production are present in one specific group of these methane-consuming organisms, but appear to be "run backwards" so that they consume rather than generate methane. Importantly, the sequencing of this microbe was completed without a requirement for individual growth and culturing of each organism in the sediments, a capability that is becoming increasingly valuable since most microbes are not readily culturable. These genome-based observations provide a foundation for metabolic modeling of methane oxidation in the absence of oxygen in the deep ocean. This will lead to a better understanding of the role these organisms play in the flux of greenhouse gases from ocean to atmosphere, information that may illuminate how oceanic microbes participate in global carbon cycling and climate processes.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Structural Biology	**21,859**	**15,084**	**15,300**
▪ **Basic Research**	**6,559**	**—**	**—**

Basic Structural Biology research is terminated to support Genomics: GTL research. Support for characterization, including imaging, of multiprotein complexes and of gene regulatory networks is transferred to Genomics: GTL.

▪ **Infrastructure Development**	**15,300**	**15,084**	**15,300**

BER 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 of experimental stations at 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.

Molecular and Cellular Biology	**103,669**	**109,670**	**159,942**
▪ **Microbial Genomics**	**8,276**	**—**	**—**

Microbial genomics is consolidated within Genomics: GTL.

▪ **Carbon Sequestration Research**	**5,581**	**7,106**	**7,127**

Microbes and plants play substantial roles in the cycling of carbon through the environment. Carbon sequestration research seeks to understand how plants and microbes work together to sequester atmospheric carbon dioxide. The program continues to leverage the genomic DNA sequence of the

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

poplar tree, completed in FY 2004, supporting research to understand the poplar genome and proteome related to carbon utilization. Research will also focus on microbes that live in the poplar rhizosphere (root zone) to understand the role these microbes play in the transfer of carbon between the roots and the soil. The program will emphasize organisms and pathways that serve to increase long-term carbon storage to identify strategies that would lead to increased carbon storage in the poplar rhizosphere and surrounding soil, such as manipulation of the soil chemical environment to promote specific microorganisms or metabolic pathways. This research leverages BER's more fundamental microbial systems biology research in Genomics: GTL and BER's terrestrial carbon cycle research to evaluate options for molecular-based terrestrial carbon sequestration.

	FY 2005	FY 2006	FY 2007
▪ **Genomics: GTL**	**72,637**	**85,486**	**135,319**

Genomics: GTL is a microbe-based program at the forefront of the biological revolution - a systems approach to biology at the interfaces of the biological, physical, and computational sciences. Genomics: GTL offers the possibility of biotechnology solutions that can give us abundant sources of clean energy, such as ethanol from cellulose or biohydrogen, yet control greenhouse gases such as carbon dioxide, a key factor in global climate change, and that can help us clean up contamination of the environment.

Genomics: GTL will require a mix of fundamental research and development of novel capabilities for new high-throughput biological research, e.g., for protein production, molecular imaging, small molecule production, and proteomics. Over the long-term, it will support a combination of fundamental research and technology development; development and use of facility infrastructure that will efficiently and cost effectively generate much needed data for the scientific community much like DNA sequencing was moved from the research laboratory to sequencing facilities in the human genome project; and demonstration projects developed in partnership with other DOE offices such as Energy Efficiency and Renewable Energy, Fossil Energy, and Environmental Management to "field test" potential 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 and will focus on high-throughput genomic-scale activities (e.g., DNA sequencing, complex computational analysis, imaging, and genomic protein-expression experimentation and analysis) that are beyond the reach of individual investigators or even small teams.

The broad goals of this research are shared with other agencies, such as the National Institutes of Health, the National Science Foundation, the Department of Agriculture, the Environmental Protection Agency, and private sector companies and will require coordination exceeding that of the Human Genome Project.

In FY 2007, the program continues to support a mix of large multidisciplinary research teams and smaller individual investigator projects to:

- develop computational models and the necessary algorithmic and computational tools needed to describe the biochemical capabilities of microbial communities; to integrate diverse data types and data sets into single models; and that accurately describe and predict the behavior of genetic regulatory networks;
- develop high-throughput approaches for isolating and characterizing microbial molecular machines;
- develop new technologies and strategies for imaging individual proteins and molecular machines inside microbes;
- develop new technologies for producing large numbers of microbial proteins and molecular tags to identify those proteins;
- develop microbe-based strategies for production of celluosic ethanol and hydrogen; and
- determine the societal and legal implications of genomics research and technology.

In FY 2007, research will also continue the high-throughput DNA sequencing of microbes and microbial communities. This DNA sequence information will continue to serve as the core of biological information needed to understand the control and function of molecular machines and complex microbial communities.

Technology development research relevant to proposed GTL user facilities is increased in FY 2007 to address key challenges. Research will be increased to develop new methods that enable scientists to “see” individual molecular machines at work inside microbes. This capability will provide information that is needed to understand the functions, regulation, and interactions of molecular machines. Aspects of proteome analysis are now very efficient and being used for large numbers of analyses. Research will be increased to improve the efficiency of components of the proteome “pipeline,” including aspects of initial sample preparation, analysis of protein modifications, and development of capabilities of high-throughput metabolite analysis. Research will also be increased to improve methods for long-term analysis of complex microbial communities in controlled environments. Only by understanding how microbes live and work together in the environment can we take advantage of their capabilities to address DOE mission needs.

SciDAC research is initiated to develop mathematical and computational tools needed for complex biological systems modeling and for analysis of complex data sets, such as those generated by mass spectrometry.

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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

The request greatly accelerates fundamental Genomics: GTL research, including SciDAC research, so that Genomics: GTL research progress will be maximized and the program is able to optimize use of potential future facility infrastructure. GTL research accelerates, including a focus on microbe-based generation of hydrogen, production of ethanol from cellulose, sequestration of carbon dioxide, and bioremediation. The program would include multiple research paths to avoid roadblocks and to optimize systems design options and would be 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 nongovernmental organizations. Increased SciDAC research would develop mathematical and computational tools needed for complex biological system modeling, for analysis of complex data sets, such as mass spectrometry, and to develop predictive models of complex microbial communities.

Within the request, $40,000,000 is for GTL research which will contribute biotechnology solutions for two biofuels: hydrogen and ethanol. Studies have suggested that, by 2100 biotechnology-based energy use could equal all global fossil energy use today. Bioethanol is derived from plant cell walls (cellulosic ethanol) and biohydrogen is produced from water using energy from the sun (biophotolytic 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 plant biomass such as corn plants left after a corn harvest or energy crops such as poplar trees, that are specifically raised as biomass for energy production. 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, the planet's dominant photosynthetic organisms, exist that can use solar energy to convert water to hydrogen and oxygen, i.e., biophotolysis.

New knowledge on biophotolysis and hydrogenases will be used to engineer the ideal microbe to use in hydrogen bioreactors or the ideal enzyme-catalyst to use in bioinspired nanostructures for hydrogen production. New knowledge on the enzymes and microbes that contribute (individually and together) to the conversion of cellulose to ethanol will be used to develop genetically modified, multifunctional microbes or a stable mixed culture of microbes capable of carrying out all biologically mediated transformations needed for the complete conversion of biomass to ethanol in a single step.

Fundamental research will be supported to understand biophotolysis, and other processes, well enough that predictive models of hydrogenase (the enzyme that cleaves water to produce hydrogen) structure and function, 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, understanding how hydrogenases work, the inhibition of hydrogenase activity by oxygen, and genetic regulatory and biochemical processes that influence hydrogen production.

Research will also be supported on a variety of enzymes and microbes that contribute (individually and together) to the conversion of cellulose to ethanol; analysis of enzymes to understand how they interact with and breakdown cellulose; a determination of the factors, such as temperature and different combinations of sugars, that influence biomass degradation or ethanol production; strategies for producing and maintaining stable mixed cultures of microbes; and improved capabilities for genetically engineering microbes that produce bioethanol.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Low Dose Radiation Research**	**17,175**	**17,078**	**17,496**

The goal of the Low Dose Radiation Research program is to support research that will help determine health risks from exposures to low levels of ionizing radiation, information 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.

Radiation studies have traditionally been carried out using isolated cells and the responses of those cells were extrapolated to tissues and organisms. We now know that cells within tissues respond very differently to radiation than do isolated cells. This difference is greatest for very low dose exposures, or for very low dose rates, because in these situations, most of the cells in a tissue would not be irradiated at all. After these low-level exposures, the few irradiated/potentially-damaged cells in the tissue are mostly surrounded and heavily outnumbered by unirradiated/undamaged cells.

We now know that tissues often "protect" themselves from abnormal cells—such as a cell damaged by radiation—and defective cells may be stimulated to undergo "altruistic suicide." Tissue function is the culmination of a multicellular network coordinated by soluble endocrine, autocrine, and paracrine signals, and linked through a scaffolding of extracellular matrix that dynamically maintains homeostasis by regulating tissue composition, function, and phenotype. Emerging data shows that for low dose exposures it is the networked, multicellular responses, rather than the damage *per se*, that dictate whether homeostasis is restored or if pathology ensues. High dose exposure may corrupt normal signaling and moderate chronic irradiation may persistently alter cellular phenotype compromising the surveillance of abnormal cells and allowing aberrant cells to accumulate and proliferate.

In FY 2007, the program has an increased emphasis on systems biology concepts to place radiation induced bystander effects, adaptive response, and genomic instability data into the context of irradiated system (i.e. tissues). Bystander effects result from cell-cell communication (extracellular signaling) and are a type of early multicellular programmed response that attempts to re-establish homeostasis and eliminate abnormal cells. Adaptive response and multi-generational radiation-induced genomic instability may result from persistent network perturbations following radiation exposures.

In FY 2007, 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.

The research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and selected through competitive and merit-reviewed processes. University scientists, competing for funds in response to requests for applications, conduct a substantial fraction of the research in this subprogram.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Human Genome	**62,941**	**62,885**	**74,575**
▪ **Joint Genome Institute**	**51,500**	**51,500**	**62,055**

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 to at least 50 billion base pairs in FY 2007 to support the increasing demand and need of the DOE research programs and the scientific community. The JGI's Community Sequencing Program (CSP) devotes 60% of its sequencing capacity to the merit-reviewed sequencing needs of the broader scientific community, including the needs of other agencies. DNA sequencing targets are chosen using peer review of requests for sequencing submitted by individual scientists and other federal agencies that share some DOE missions (for example USDA for Biomass). In FY 2007, the CSP will sequence approximately 30 billion base pairs of DNA from individual microbes, microbial communities, small plants and animals, and large plants and animals that will be selected by the CSP's merit review panel in FY 2006. Any large genomes selected for sequencing through the CSP will be required to meet the additional criteria of general relevance to DOE mission needs. Forty percent of the JGI's DNA sequencing capacity is being used to address DOE sequencing needs, including BER programs such as carbon sequestration research and bioremediation research, low dose radiation research and other DOE and national needs. The substantial high-throughput DNA sequencing needs of the GTL program ($10M) are supported at the JGI directly by the Genomics: GTL program and are not included here. These GTL funds 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.

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 sequencing factory is located in Walnut Creek, California.

In FY 2007, the increased funding supports an increase of 15% in the DNA sequencing capacity for DOE and the scientific community.

▪ **Tools for DNA Sequencing and Sequence Analysis**	**9,594**	**9,785**	**10,520**

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

The research activities in this subprogram are carried out at the JGI, national laboratories, universities, and private institutions and selected through competitive and peer-reviewed processes.

In FY 2007 the increased funding will support additional efforts to develop high-throughput annotation methods that keep pace with the rapidly increasing rate of DNA sequencing.

	FY 2005	FY 2006	FY 2007
	(dollars in thousands)		
▪ **Ethical, Legal, and Societal Issues (ELSI)**	**1,847**	**1,600**	**2,000**

In FY 2007, ELSI research will increase and complete the refocusing of ELSI research on activities applicable to Office of Science issues in biotechnology and nanotechnology such as environmental or human health concerns associated with Genomics: GTL or nanotechnology research. Research with these funds will be coordinated across the Office of Science. The increased funding will support the first full year of research in the newly refocused ELSI program.

Health Effects	**10,174**	**8,808**	**7,321**

Functional genomics research is a key link between human genomic sequencing, that provides a complete parts list for a genome, and the development of information (a high-tech owner's manual) that is useful, in the case of human, in understanding normal human development and disease processes. The mouse continues to be the focus of our efforts. Research at BER's Center for Comparative and Functional Genomics user facility at Oak Ridge National Laboratory serves as a national focal point for high-throughput genetic studies using mice. This facility creates and genetically characterizes new mutant strains of mice that serve as important models of human genetic diseases and for understanding gene function especially as they relate to the genetic information found on human chromosomes 5, 16, and 19 (DOE's chromosomes in the International Human Genome Project). It also develops high-throughput tools and strategies to characterize these mice. This user facility provides tools useful to the entire scientific community for decoding the functionality of the human genome.

The research activities in this subprogram are principally carried out at National Laboratories, selected through merit-reviewed processes.

In FY 2007, the decreased funding will reduce research on animal models for disease associated with exposures to energy-related materials.

SBIR/STTR..	**—**	**5,548**	**7,020**

In FY 2005 $4,816,000 and $577,000 were transferred to the SBIR and STTR programs, respectively. FY 2006 and FY 2007 amounts are the estimated requirements for continuation of the programs.

Total, Life Sciences...	**198,643**	**201,995**	**264,158**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Structural Biology	
▪ Structural Biology Infrastructure Development is held near FY 2006 levels.	+216
Molecular and Cellular Biology	
▪ Carbon Sequestration Research is held near FY 2006 levels..	+21

	FY 2007 vs. FY 2006 ($000)
▪ Genomics: GTL research will be increased to speed development of technologies that underpin proposed facility infrastructure including high-throughput methods for real time imaging of molecular machines inside microbial cells, for reducing current bottlenecks in high-throughput proteomics, and for improved methods for studying complex microbial communities in controlled environments. The increase also funds the following: greatly accelerates fundamental Genomics: GTL research, so that Genomics: GTL research progress will be maximized and the program is able to optimize use of potential future facility infrastructure. It also includes enhanced SciDAC Research, microbe-based generation of hydrogen and production of ethanol from cellulose, sequestration of carbon dioxide, and bioremediation. The program would include multiple research paths to avoid roadblocks and to optimize systems design options and would be 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 nongovernmental organizations. Increased SciDAC research would develop mathematical and computational tools needed for complex biological system modeling, for analysis of complex data sets, such as mass spectrometry, and to develop predictive models of complex microbial communities.....	+49,833
▪ Low Dose Radiation Research is held near FY 2006 levels.	+418
Total, Molecular and Cellular Biology	**+50,272**
Human Genome	
▪ Joint Genome Institute increases DNA sequencing capacity for DOE and the scientific community by an additional 15% to support increased scientific need for genomic DNA sequencing in BER programs and in the broader scientific community. Tools for DNA Sequencing and Sequence Analysis research increases to continue development of high-throughput approaches for analyzing gene regulation and function	+10,555
▪ Tools for DNA Sequencing and Sequence Analysis research increases to continue development of high-throughput approaches for analyzing gene regulation and function.	+735
▪ ELSI research increases to identify and understand the environmental or human health concerns of Genomics: GTL research…	+400
Total Human Genome	**+11,690**
Health Effects	
▪ Health Effects research decreases research on animal models for disease associated with exposures to energy-related materials. The support for the mouse user facility, the Center for Comparative and Functional Genomics, continues at FY 2006 levels.	-1,487

	FY 2007 vs. FY 2006 ($000)
SBIR/STTR	
▪ Increases in SBIR/STTR due to increases in Life Sciences research funding	+1,472
Total Funding Change, Life Sciences	**+62,163**

Climate Change Research

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Climate Change Research			
Climate Forcing	74,346	78,980	77,831
Climate Change Modeling	27,507	26,680	25,175
Climate Change Response	25,132	24,986	23,181
Climate Change Mitigation	8,550	6,947	5,014
SBIR/STTR	—	3,936	3,708
Total, Climate Change Research	135,535	141,529	134,909

Description

The mission of the Climate Change Research subprogram is to deliver relevant scientific knowledge that will enable scientifically based predictions and assessments of the potential effects of greenhouse gas and aerosol emissions on climate and the environment.

Benefits

This subprogram's research will reduce and resolve key uncertainties and provide the scientific foundation needed to predict, assess, and help mitigate adverse effects of energy production and use on the environment. This will be done through research on climate forcing and processes, including factors that affect climate forcing, such as clouds and aerosols and carbon cycling, climate change modeling and simulation to develop models needed to project what the likely response of the climate system would be in the future to natural and human-induced climate forcing, the response of ecological and human systems to ongoing and projected future changes in climate and atmospheric composition associated with energy production, and climate change mitigation, specifically research that could lead to the development of strategies or technologies for modifying or managing natural carbon sequestration processes in terrestrial systems to enhance their potential.

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 from fossil fuel combustion, how the climate system would likely respond to human-induced and natural changes in radiative forcing, what the potential response would be of ecological and ecosystem systems to climatic changes, and how natural processes in terrestrial and ocean systems 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/carbon sequestration element in Climate Change Research plus carbon sequestration activity in the Life Sciences subprogram are BER's contribution to the CCTP.

The CCRI is a set of cross-agency programs in areas of high priority climate change research where substantial progress is anticipated over the next three to five years. The specific focus areas include climate forcing (atmospheric concentrations of greenhouse gases and aerosols); climate feedbacks and sensitivity; climate modeling, including enabling research; regional impacts of climate change, including environment-society interactions; and climate observations. In FY 2007, BER will continue to participate in one of the specific research areas: climate forcing, which includes modeling carbon sources and sinks, especially those in North America. In FY 2007, BER will continue to support research to quantify the magnitude and location of the North American carbon sink, a high priority need identified in the interagency Carbon Cycle Science Plan, and on climate modeling, Atmospheric Radiation Measurement (ARM), and Integrated Assessment activities (BER's FY 2007 CCRI request is $23,750,000).

A major emphasis of the Climate Change Research subprogram is on understanding climate forcing, especially the radiation balance from the surface of the Earth to the top of the atmosphere and how changes in this balance due to increases in the concentration of greenhouse gases in the atmosphere may alter climate. Much of the research is focused on improving the quantitative models necessary to predict possible climate change at global and regional scales. Research in the ARM program will continue to focus on resolving the greatest scientific uncertainty in climate change prediction – the role of clouds and their interactions with solar radiation. ARM seeks to develop a better quantitative understanding of how atmospheric properties, including the extent and type of cloud cover and changes in aerosols and greenhouse gas concentrations, affect the solar and infrared radiation balance that drives the climate system. It also includes support to archive and analyze climate change data, including data from the ARM sites, and data on greenhouse gas emissions and concentrations and to make such data available for use by the broader climate change research community.

The Atmospheric Science program was reconfigured in FY 2005 to focus 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 radiative forcing effect on climate. In FY 2007, the program will continue studies of the physical, chemical, and radiative properties of aerosols and how much they may directly or indirectly affect the radiation balance.

Research on the carbon cycle explores the movement of carbon on a continental scale, starting from natural and anthropogenic emissions to ultimate sinks in the terrestrial biosphere and the oceans.

Experimental and modeling efforts primarily address the net exchange of carbon between major types of terrestrial ecosystems and the atmosphere. The focus in developing an understanding and ability to model the processes controlling the exchange of carbon dioxide between terrestrial systems and the atmosphere and how these processes may affect the atmospheric concentration of carbon dioxide which contributes to climate forcing.

Climate change modeling program element develops advanced, fully coupled, atmosphere-ocean-sea ice-land surface climate models and uses premier supercomputers to simulate and predict climate and climate change, including evaluating uncertainties in climate models due to changes in atmospheric levels of greenhouse gases on decade-to-century time scales. The focus is on developing, testing, improving, and applying state-of-the art climate models for assessing the potential for future climate changes due to natural and human-induced forcing of the climate system.

Ecological Processes research is focused on experimental and modeling studies to understand and predict the effects of climate and atmospheric changes on the biological structure and functioning of terrestrial ecosystems. The research also seeks to identify the potential feedbacks from ecosystems to climate and atmospheric composition. The research emphasizes major field studies of intact ecosystems using experimental manipulations of, for example, carbon dioxide and ozone concentrations and precipitation, and using data from these experiments to develop, test, and improve models for simulating and predicting ecosystem responses to environmental changes associated with energy production and use. The research also focuses on the causal mechanisms and pathways of biological and ecological responses ranging from the proteome of individual species to the whole ecosystem and will develop advanced computational models to establish how changes in the proteomes of single species or whole systems can explain the responses and behavior of complex ecosystems.

Human Interactions research is focused on improving methods and models that can be used to assess the economic and societal costs and benefits of both human-induced climate change and possible response options or strategies for mitigating or adapting to climate change.

The carbon sequestration element under Climate Change Mitigation funds basic research that seeks to exploit the biosphere’s natural processes to enhance the sequestration of atmospheric carbon dioxide in terrestrial ecosystems. It also seeks the understanding needed to assess the potential environmental implications of purposeful enhancement and/or disposal of carbon in the terrestrial biosphere. The carbon sequestration activities include research to identify and understand the environmental and biological factors or processes that limit carbon sequestration in terrestrial systems and to develop approaches for overcoming such limitations to enhance sequestration. The research includes studies on the role of terrestrial microorganisms and terrestrial higher plants in carbon sequestration.

Periodic retrospective analysis is employed to evaluate program management processes, priorities, and outcomes. A BERAC 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 COV found the Climate Change Research subprogram to be a credit to DOE and an example of the way that Executive agencies should operate. It also found many of the programs within the subprogram to be unique. The COV concluded that the Climate Change Research programs are productive and support high quality research that plays an important role in the DOE and especially in the interagency U.S. Climate Change Science Program. The COV found the Climate Change Research subprogram to be generally well managed, but noted the need to improve documentation of the basis for proposal funding decisions, and the performance and outcomes of Climate Change Research programs. BER has taken action to address these findings.

The full report and the BER response are at http://www.science.doe.gov/ober/berac.html.

FY 2005 Accomplishments

- Release of New Version of Fully-Coupled Climate System Model: The most recent version of the Community Climate Model System, CCSM3.0, which is a fully coupled atmosphere-ocean-sea ice-land surface model, was released. Its release marks a significant milestone in the development of climate models that now incorporate the ability to simulate phenomena ranging from the effect of volcanic eruptions on temperature patterns to the impact of shifting sea ice on sunlight absorbed by the oceans. The model was developed at the National Center for Atmospheric Research in collaboration with researchers at universities and DOE laboratories, with major investments from DOE's climate modeling program. Model results and the underlying computer codes have been released to atmospheric researchers and other users worldwide. Scientists have applied the new model to generate scenarios of future potential climate change for use in preparing the Intergovernmental Panel on Climate Change's Fourth Assessment Report (IPCC AR4). Preliminary results of simulations of future climate states using CCSM3.0 indicate global temperatures could rise by 2.6 degrees Celsius (4.7 degrees Fahrenheit) in a hypothetical scenario in which atmospheric levels of carbon dioxide are suddenly doubled. That is significantly more than the 2 degree Celsius (3.6 degree Fahrenheit) increase that had been indicated by the preceding version of the model. In addition to simulating temperatures over the next century, scientists are using the model to study climate patterns of the past, such as the peak of the last ice age 21,000 years ago. It will also be used to probe chemical processes and the cycling of carbon between the atmosphere, ocean, and land, as well as the localized impacts of sulfates and other pollutants on climate.
- Climate Model Simulates Occurrence of Extreme Heat Wave Events Under Greenhouse Gas Forcing Climate Change Scenario: Results under a 'business-as-usual' scenario of future carbon dioxide emissions using a global coupled climate model indicate a distinct geographic pattern to future simulated changes in heat waves. Model results for areas of Europe and North America, associated with the severe heat waves in Chicago in 1995 and Paris in 2003, show that future heat waves in these areas will become more intense, more frequent, and longer lasting in the second half of the 21st century. Observations and the model results show that present-day heat waves over Europe and North America coincide with a specific atmospheric circulation pattern that is intensified by ongoing increases in greenhouse gases, indicating that it will produce more severe heat waves in those regions in the future. This research was jointly sponsored by BER and the National Center for Atmospheric Research.
- Regional Climate Model Simulates Global "Warming Hole" in Central United States: A local minimum warming ("warming hole") in summer over the central United States was predicted for the next few decades using a regional climate change model. Although the simulated daily maximum temperature in the "hole" increased in summer between the 1990s and 2040s, the simulated increase in the "hole" was 2.0-2.5°C (about 4°F) less than in the surrounding area. This projected "warming hole" coincides roughly with an observed "hole" in the warming of the last 25 years of the 20th century in the central United States. The simulation showed that the "hole" was associated with changes in low-level circulations that lead to replenishment of seasonally depleted soil moisture, thereby increasing late-summer evapotranspiration and suppressing daytime heating. These regional-scale feedback processes, which are unresolvable by most global climate models, may partly explain

the cooling trend in the central and eastern United States occurring in spite of global warming, and potentially could reduce the magnitude of future warming in the region due to the enhanced greenhouse effect caused by increasing carbon dioxide concentration in the atmosphere.

- ARM Mobile Facility (AMF) Completed and Deployed to Study Clouds and Aerosols: With instrumentation and data systems similar to ARM stationary sites at the North Slope of Alaska and the Tropical Western Pacific, fabrication of the AMF has been completed for deployment to sites around the world in various climatic regimes for durations of 6 to 18 months. Following a competitive peer review deployments were selected for 2005 and 2006. In 2005, researchers from the ARM Program deployed the facility at Pt. Reyes, California and in collaboration with scientists from the U.S. Office of Naval Research, NOAA, and DOE's Atmospheric Science Program began a 6-month campaign to study the interactions between marine stratus clouds and aerosols and the effect of such interactions on the absorption and scattering in incoming solar radiation and drizzle. The experiment addresses the specific effects of aerosols on the discrepancy between the measured and modeled amount of solar radiation absorbed by these clouds. In 2006, the AMF will be deployed at Niamey, Niger, Africa, as part of the field phase of the international African Monsoon Multidisciplinary Analysis (AMMA). The campaign will study meteorological conditions ranging from deep, tropical convective clouds in the humid tropical air masses prevalent in the wet season to the aerosol-laden dry air masses found during the dry season. These campaigns will provide unique opportunities for evaluating and improving the parameterization schemes used in climate models across a wide range of meteorological conditions.
- New Parameterization Improves Climate Simulations: The addition of a new ARM-developed parameterization scheme for convection to the Community Atmosphere Model (known as CAM3) has resulted in a remarkable improvement in the simulation of climate and its variability on intraseasonal timescales in the Tropics. In particular, several long-standing model biases, including the dual Intertropical Convergence Zones in the Equatorial Pacific Ocean are eliminated when the new parameterization is used in the model. The new parameterization improved simulations for precipitation in both winter and boreal summer seasons and more accurately simulates the annual cycle of the monsoon precipitation. The new convection parameterization also improves the simulation of tropical intraseasonal variability.
- Carbon Balance of Western Montane Coniferous Forest found to be Sensitive to Timing of Spring Warming: Montane forests are responsible for much of the atmospheric CO_2 assimilated by terrestrial ecosystems in the western United States. This poses challenges for accurate quantification of ecosystem carbon balance and dynamics because the current generation of CO_2 exchange measurement systems and approaches are designed to function in relatively flat, simple terrain. Using a specially designed multiple tower system, it was shown that when current measurement methods are deployed in mountainous terrain without special accommodation for the complex topography, the annual net CO_2 uptake by forests is underestimated by about 17%. When corrected for complex topography, a subalpine forest in Colorado was found to store about 100 g C m^{-2} each year (5-year average). This annual net CO_2 uptake was sensitive to interannual climatic variation, with the most sensitive period being the early spring (April and May), when as much as 40% of the annual net CO_2 uptake can occur within a 30-day period. During years when spring warming occurred early, as is predicted for the future by climate models, annual net CO_2 uptake by the forest declined; this is contrary to studies in eastern deciduous forest ecosystems, where earlier spring warming is predicted to enhance annual net CO_2 uptake. This divergence may be due to differences

between the evergreen trees that dominate western forests and the winter-deciduous trees that dominate eastern forests.

- Genetic Diversity and Gene Expression of Carbon Fixation Influence Carbon Fixation and Potentially Carbon Sequestration in Gulf of Mexico area affected by Mississippi River Plume: The Mississippi River Plume strongly influences the biology, chemistry, physics, and the air-sea interactions of much of the Gulf of Mexico, including the atmospheric humidity and CO_2 levels of the southeastern United States. The biological processes occurring in this plume largely dictate whether it takes up or releases atmospheric CO_2. Using primary productivity and remote sensing analyses, it was shown that the offshore Mississippi River Plume is responsible for about 40% of the surface primary productivity in the low nutrient waters of the Gulf of Mexico. Nutrient uptake, biological productivity, and gene expression analyses revealed two alternative routes for CO_2 fixation in the Plume: (1) a cyanobacterial-driven uptake which likely leads to only short-term carbon storage in the ocean and (2) a diverse, diatom driven uptake which may contribute to longer-term carbon storage (removal from the atmosphere) in the ocean. The genetic sequence information that was collected will enable quantification of phytoplankton group-specific gene expression in the environment, providing new insights about the role of the Mississippi River Plume in controlling atmospheric CO_2 increase.

- Can Iron Fertilization of the Ocean be both Effective and Efficient at Sequestering Carbon? An investigation into the effectiveness of iron fertilization of the ocean surface as a means to increase the efficiency of the biological pump of carbon in waters of the Ross Sea, Antarctica was conducted using the CIAO ecosystem model. Results indicate that the stimulation of air-sea CO_2 exchange caused by iron fertilization depends primarily on the timing of the fertilization, regardless of the amount of iron added. Increasing the area of fertilization produced the largest response and increasing initial iron concentration produced the smallest, in the model. In all cases, as the intensity of iron fertilization increased, the fertilization efficiency (CO_2 uptake per unit iron added) dropped. Strategies that maximized the fertilization efficiency resulted in relatively little additional CO_2 being drawn out of the atmosphere. Conversely, to markedly increase oceanic uptake of atmospheric CO_2 would require the addition of large amounts of iron due to the low fertilization efficiencies associated with maximum air-sea CO_2 exchange.

- Hydrate Reactor Developed to Improve Efficiency of Deep Ocean Injection for Carbon Sequestration: A continuous-jet hydrate reactor was developed to efficiently produce dense, negatively buoyant (i.e., sinking) CO_2 hydrate particles for the purpose of carbon sequestration via direct injection of CO_2 into the deep ocean. The technical feasibility of the reactor was proven at Oak Ridge National Laboratory using a 72-liter seafloor process simulator and at the National Energy and Technology Laboratory using a high-pressure water tunnel facility. Field verification of laboratory results was demonstrated in Monterey Bay, California, using the facilities of Monterey Bay Aquarium Research Institute. Prior to this, methods for direct injection of CO_2 into the deep ocean were inefficient because the injection of liquid CO_2 alone produces buoyant droplets with the risk of returning to the ocean surface and atmosphere rather than remaining in the ocean for long periods required for effective carbon sequestration.

- Deep Ocean Injection of CO_2 harmful to deep-sea organisms: Effects of injected CO_2 on foraminiferal assemblages living at 3600 meter depth on the deep-sea floor were evaluated during the first field experiment off the coast of California. Foraminifera, commonly referred to as "forams" are single-celled protists with shells and range in size from 100 micrometers to almost 20 centimeters (cm). Most of the estimated 4,000 living species of forams are found in the world's oceans. Injection of CO_2 into the deep ocean has been proposed as means to sequester carbon and slow the increase in atmospheric CO_2 concentration. Results from this study imply almost complete initial mortality of forams and severe carbonate dissolution of the shells of forams in ocean sediments to depths of at least 10 cm into the sediment in close association to the point of CO_2 injection. This results in major decreases in the abundance and taxonomic diversity in both living and dead assemblages of forams on the sea floor. A second, shallower (3100 meter depth) experiment confirmed total mortality in at least the upper 1 cm of sediments and dissolution effects to even greater depths, which are still being determined. Benthic foraminifera are therefore now known to be highly vulnerable to CO_2 injection into the deep ocean.

- Forest Food Chain Dynamics Altered by Elevated Atmospheric Carbon Dioxide and Ozone Concentrations: BER constructed, maintains, and operates a large-scale field research facility in northern Wisconsin to study effects of experimentally elevated concentrations of carbon dioxide and ozone on the structure and functioning of hardwood forest ecosystems (concentrations of both gases are increasing because of energy production from fossil fuels). The forest being studied, a constructed mixture of aspen, birch, and maple trees, has been exposed to elevated carbon dioxide and ozone since 1997. Scientists recently discovered that elevated levels of these two gases can alter the feeding and reproduction of herbivorous insects, as well as their pheromone-mediated predator escape behaviors. For example, the efficacy of insect escape responses appears to increase under elevated O_3 but decrease under elevated CO_2. These results indicate that shifts in the dynamics of trees, the insects that feed on them, and the predators that feed on those insects could be altered by ongoing changes in atmospheric composition, with implications for the future health of forests.
- Enhanced Monsoon could alter Mojave Desert vegetation: Many climate models predict an enhanced monsoon in the southwestern United States, which could include additional rain in the Mojave Desert. Three years of a field experiment in the Mojave Desert, including added summer rain (three 25 millimeter events) have resulted in stimulation of growth in the dominant perennial plants. Deeper penetration into the soil of wetting fronts caused by added summer rain resulted in increased depth of root growth of several shrubs, including creosote bush. These results indicate that an enhanced future monsoon in the Southwest might change the structure and functioning of Mojave Desert scrub plant communities in favor of more deep-rooted plants capable of exploiting this additional moisture.
- Warming and increased carbon dioxide concentration accelerates succession in terrestrial ecosystem: The warmer temperatures and increased atmospheric carbon dioxide concentrations associated with urban areas, relative to upwind rural areas, was used to study effects of warming and rising carbon dioxide levels on the early stages of ecosystem secondary succession (i.e., the development of an ecosystem following a disturbance). The warming and elevated carbon dioxide levels now associated with urban Baltimore broadly reflect conditions expected about 50 years from now in rural areas. The present Baltimore conditions increased plant growth, including the growth of weedy species, and accelerated a shift from annual herbaceous species to perennial plant species, including young trees. The results indicate that warming and increasing carbon dioxide concentration may both enhance plant growth and accelerate successional processes following ecosystem disturbance in Maryland and in ecologically and climatically similar regions.
- New Ecological Research Facility Becomes Operational: A research facility at the Oak Ridge National Laboratory was established for studying the effects of atmospheric CO_2 enrichment, warming, and altered soil moisture on old-field ecosystems, which represent an important stage of recovery from disturbance in many ecosystems. Plants typical of old-field communities were

established within field chambers. Chamber air is modified to provide current or elevated (+300 ppm) CO_2 concentration in combination with near-current (+0.5 °C) or elevated (+3.2 °C) temperature. Rain is excluded from the ecosystems and water is added to maintain wet or dry soil conditions. Effects of these environmental changes on the organisms within these ecosystems, and the ecosystems themselves, will be quantified during coming years. The establishment of this research facility meets a near-term milestone of the U.S. Climate Change Science Program.

- Soil communities altered by elevated atmospheric carbon dioxide and ozone concentrations: Soil microorganisms depend on plant litter (dead plant parts) as a source of food, therefore, increases in plant litter production caused by elevated CO_2 and declines in litter production caused by elevated O_3 could alter microbial community composition and functioning. Exposure of aspen, aspen-birch, and aspen-sugar maple stands to elevated carbon dioxide resulted in greater fungal metabolism of plant litter, whereas exposure of the trees to elevated ozone eliminated this response. Molecular analysis of fungal DNA in the soils under the trees revealed that elevated carbon dioxide favored a community of litter degrading fungi that was ecologically distinct from that favored by elevated O_3; both differed from the fungal community under the present ambient atmosphere. Results indicate that fungal community composition and activity in soils (and perhaps biodiversity) will be modified as atmospheric concentrations of carbon dioxide and ozone continue to change.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Climate Forcing	**74,346**	**78,980**	**77,831**
▪ **Atmospheric Radiation Measurement (ARM) Research**	**12,243**	**13,731**	**14,765**

In FY 2007, 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 increased funding will be used to 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 about 50 principal 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 new 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

European Center for Medium-Range Weather Forecasting in the U.S. In addition, a model parameterization test bed that was fully implemented in FY 2004 will be 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 2005	FY 2006	FY 2007
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**	**34,343**	**35,214**	**35,174**

In FY 2007, the ARM infrastructure will continue to support and maintain three stationary ARM Cloud and Radiation Testbeds (CART) facilities and associated ground-based instrumentation. It will also support the maintenance, upgrading and deployment of the ARM mobile facility. It will also continue to support application of the ARM Unmanned Aerial Vehicle for use in field campaigns around the ARM facilities to provide sustained measurements at different altitudes of cloud and atmospheric properties and processes. BER will continue to operate over two hundred instruments for charactering atmospheric properties and processes and measuring solar and infrared radiation at the Southern Great Plains facility. It will also continue operations at the Tropical Western Pacific ARM facility and the North Slope facility in Alaska. The ARM program will continue to provide data to the scientific community through the ARM Archive.

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). 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 have become 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, have used the ARM facilities to "ground truth" measurements made with some of their satellite-based instruments. The ARM program, including the ARM UAV, 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. In FY 2007, the ARM mobile facility will be deployed at a site in the Arctic during the International Polar Year to study the impact of clouds, aerosols and surface characteristics on the arctic climate. Activities will be coordinated with other U.S. agencies and Arctic countries, such as Canada, Russia, and Norway. Data products will continue to be developed through collaboration with model developers.

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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Atmospheric Science**	**13,017**	**12,552**	**12,551**

The CCSP 10-year Strategic Plan raised the priority of research dealing with the direct and indirect effect of atmospheric aerosols on climate. As a result, BER restructured the entire Atmospheric Science Program in FY 2005 to focus on research dealing with aerosol properties and processes and their effect on radiation and climate.

In FY 2007, the Atmospheric Science Program (ASP) will continue to characterize the physical, chemical, and optical properties of energy-related aerosols and their potential effects on 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 support 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. The ASP will also 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 2007 aimed at determining the sources, chemical and physical properties and radiative properties of aerosols derived from a major urban area. In addition, data collection from the field campaign conducted downwind of Mexico City, Mexico in 2006 will be analyzed and results will be used to develop and test new schemes for modeling aerosol transformation processes, including the chemical, physical, and optical properties of aerosols and aerosol precursors emitted from this large urban area.

Research activities in this subprogram are carried out by scientists at National Laboratories, universities and private institutions and are selected through competitive and merit-review processes.

▪ **Terrestrial Carbon Processes**	**11,254**	**12,480**	**13,332**

In FY 2007, BER will continue support of the AmeriFlux program, a network of research sites that measure the net exchange of carbon dioxide, energy, and water between the atmosphere and major terrestrial ecosystems in North America. These 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.

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. The increased funding in FY 2007 will be used to support additional

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

process studies that are needed to interpret the observed variation in carbon fluxes at some of the AmeriFlux sites.

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.

In FY 2007, 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 about 15-20 of 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 region of North America.

Research activities in this subprogram are carried out at National Laboratories, universities, and private institutions and are selected through competitive and merit-review processes.

▪ **Ocean Sciences**	**1,622**	**3,130**	**136**

Ocean sciences research is concluded. DOE has met its commitment to the scientific community to support the analysis of ocean carbon data. Analysis of ocean carbon data and modeling of ocean carbon cycling is being done by other agencies (e.g., NSF, NOAA, and NASA) eliminating the need for continuing DOE investments in these areas. Funding will be used to support one investigator to write and publish a summary article describing the major results and accomplishments of BER's ocean carbon cycle research.

▪ **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 of greenhouse gases, industrial emissions of greenhouse gases, greenhouse gas fluxes from terrestrial systems, ocean pCO_2 data, and air quality data. Disseminating such data 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 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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Climate Change Modeling	**27,507**	**26,680**	**25,175**

Model-based climate prediction provides the most scientifically valid way of predicting the response of the climate system to current and future changes in natural and human-induced forcing of the climate system over decade to century time scales. BER will continue to develop, improve, evaluate, and apply the best coupled atmosphere-ocean-sea ice-land surface models (GCMs) that simulate climate variability and over these time scales. The goal is to achieve statistically accurate forecasts of climate over regions as small as river basins using ensembles of model simulations. The ensembles will accurately incorporate the dynamic and thermodynamic feedback processes that influence climate, including clouds, aerosols, and greenhouse gas forcing. Current predictions are limited by 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 present models that are being improved and future models that are under development. 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 present and future climate models. BER will emphasize research to develop and employ information technologies that can quickly and efficiently work with large and distributed data sets of both observations and model predictions to produce quantitative information suitable for studies and assessments of climate change at regional to global scales. BER will also continue to fund the multi-institutional research consortia established in FY 2001 to further the development of comprehensive coupled GCMs for climate prediction that are of higher resolution and contain accurate and verified representations of clouds and other important climate processes. In FY 2007, BER will continue the partnerships with the Advanced Scientific Computing Research program. This includes applying the computing resources for climate simulation and continuing the improvement and development of climate model codes so they run efficiently across a wide variety of computing platforms. In addition, BER will continue to emphasize the development and application of data assimilation methods so as to quickly make use of the high-quality observational data streams from the ARM program, satellites, and other CCSP climate change programs to evaluate model performance.

In FY 2007, BER will focus on providing important input to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, specifically model-based scenarios of future potential climate change to different natural and human-induced climate forcing scenarios. Support for both the CCPP-ARM parameterization testbed and CCPP university research grants that complement current SciDAC computational research for climate modeling will be reduced. The model projections generated for the Fourth IPCC 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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

In FY 2007, BER's SciDAC program ($9,720,000) will continue to focus on providing models used for climate simulation and prediction. This will include the development and implementation of coupled earth system models that can simulate the interactions between the climate system and the carbon cycle, the effect of sulfate aerosols on climate, and the effect of land cover changes on climate. Efforts will also be continued to provide software engineering support for the Community Climate System Model, a code used by hundreds of researchers on many different high-end computing platforms. Research will also continue on the development of a prototype climate model of the future using new approaches to modeling climate.

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

	FY 2005	FY 2006	FY 2007
Climate Change Response..	**25,132**	**24,986**	**23,181**
▪ **Ecosystem Function and Response**.....................	**13,896**	**12,934**	**11,583**

In FY 2007, ecological research will continue to develop more mechanistic understanding of the scales of response of complex ecological systems to environmental changes, including identifying the underlying causal mechanisms and pathways and how they are linked, ranging from the proteomes of individual species to the whole ecosystem. The focus will be on understanding the responses of ecological systems to climatic and atmospheric changes, especially the linkages of scales in model terrestrial ecosystems containing simplified but hierarchical communities (e.g., higher plants, consumers of plant production, and microbes that decompose plant material and mineralize nutrients essential for plant growth). A key environmental factor (e.g., temperature, CO_2 concentration, nutrient supply) that is known to affect ecosystem functioning is experimentally manipulated and responses of individual species and the whole ecosystem will be measured at different scales, ranging from the proteome and/or genome of individual species to the entire community and ecosystem. Advanced biologically-based computational algorithms and ecosystem models will be developed to establish whether and how genomic changes (in single species, communities or whole systems) explain the responses and behavior of the entire complex ecosystem. Tools and principles developed from this research is expected to have broad generality and eventual application to problems in ecological risk assessment, carbon sequestration, environmental restoration and cleanup, and early detection of ecological responses to climatic and atmospheric changes and other environmental factors.

In FY 2007, BER will focus on supporting experimental research at the four Free-Air Carbon Dioxide Enrichment (FACE) sites located at Duke University (North Carolina), Rhinelander, Wisconsin, Oak Ridge, Tennessee, and Mercury Nevada on the Nevada Test Site. Support for other on-going or new experimental studies will be reduced. The on-going experiments will improve understanding of the direct effects of experimentally elevated carbon dioxide and other atmospheric changes (such as elevated ozone) on the structure and functioning of various terrestrial ecosystems, including their capacity to sequester carbon at the elevated level of atmospheric carbon dioxide. Emphasis will continue to be on understanding the cause of differential responses of plant species that may impact plant competition, succession, and productivity of terrestrial ecosystems. Research will also continue to explore changes over time in the effects of elevated atmospheric carbon dioxide

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

concentrations on net primary productivity and the allocation of fixed carbon to soil and living biomass in either plant roots or aboveground stems and branches or both.

The long-term experimental investigation of altered precipitation on an eastern deciduous forest at Oak Ridge, Tennessee will continue to improve understanding of the direct and indirect effects of changes in the annual average precipitation amount on the structure and functioning of this forest. Both the four FACE facilities and the altered precipitation experiment at Oak Ridge represent scientific user facilities that have attracted scientists from both academic institutions and government laboratories who use these facilities to test scientific hypotheses related to ecosystem responses to climatic and atmospheric changes.

▪ **Free Air Carbon Enrichment (FACE) Facility**..	**5,697**	**5,796**	**5,400**

In FY 2007, BER will continue to provide support to maintain and operate the four up-graded FACE facilities located at Rhinelander, Wisconsin, Mercury, Nevada on the Nevada Test Site, Duke Forest and Duke University, North Carolina, and Oak Ridge, Tennessee. The funding decrease is a result of completion of the upgrade of the FACE facilities. These four experimental field facilities provide semi-controlled environments for use by investigators to test hypotheses about the direct and indirect effects of elevated carbon dioxide and/or other gases on the structure and functioning of different terrestrial ecosystems. Funds for the FACE facility will continue to be used to maintain the four experimental facilities, including the purchase of carbon dioxide, the purchase of electricity to operate the facility, the logging of data on facility operations, and, when necessary, replacement of instruments, control systems and materials that are essential for continued, safe operation of the facilities. It includes support of staff required to operate and maintain the facilities so as to ensure they meet the experimental requirements of users. The four FACE facilities and scientific user facilities attract scientists from academic institutions, government laboratories, other countries, and other agencies to test specific hypothesis and to collect data required to answer specific scientific questions.

▪ **Integrated Assessment**	**4,118**	**4,830**	**4,772**

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 possible actions to mitigate global climate change. The goal is to improve the integrated assessment models to include several greenhouse gases, and international trading of emission permits. Model improvements are needed to better represent the efficiency gains and losses of alternative emission reduction plans, including market adjustments to interregional differences among relative energy prices, regulations, and production possibilities in the international arena.

The Integrated Assessment Program will support research to develop internally consistent sets of scenarios that can be used for national-scale decision making. The scenarios will be evaluated in selected integrated assessment models also funded by the program.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Education**	**1,421**	**1,426**	**1,426**

BER's Global Change Education Program will continue to support DOE-related research in climate change for both undergraduate and graduate studies through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREF). Both the GREF and the SURE provide students with the opportunity to propose and 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. The SURE continues to be a magnet for highly qualified undergraduates most of whom have gone on 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. Both SURE and GREF will be continued in FY 2007 to support climate change research by undergraduate and graduate students and thereby contribute to the training of students for future careers in climate change research.

Climate Change Mitigation	**8,550**	**6,947**	**5,014**

Ocean carbon sequestration research is concluded in FY 2006. This is due to adverse effects 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 2007, BER's carbon sequestration research will focus only on terrestrial carbon sequestration. Research will continue on studies to identify and understand the biological and environmental processes (e.g., carbon assimilation, retention and storage) that limit or constrain carbon sequestration in terrestrial ecosystems and to develop approaches (e.g., genetic selection, microbial manipulation, and soil carbon management) for overcoming such limitations to enhance sequestration long-term storage pools in terrestrial vegetation and soils. 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	**—**	**3,936**	**3,708**

In FY 2005 $3,476,000 and $418,000 were transferred to the SBIR and STTR programs, respectively. FY 2006 and FY 2007 amounts are the estimated requirements for continuation of the programs.

Total, Climate Change Research	**135,535**	**141,529**	**134,909**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Climate Forcing	
▪ The ARM research increases to 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.	+1,034
▪ The ARM infrastructure remains at near FY 2006 levels.	-40
▪ Atmospheric Sciences is held at FY 2006 levels.	-1
▪ Terrestrial Carbon Processes research increases to support additional process studies that are needed to interpret the observed variation in carbon fluxes at some of the AmeriFlux sites.	+852
▪ Ocean Sciences research is concluded. DOE has met its commitment to the scientific community to support the analysis of ocean carbon data. Analysis of ocean carbon data and modeling of ocean carbon cycling is being done by other agencies (e.g., NSF, NOAA, and NASA) which negate the need for continuing DOE investments in those efforts.	-2,994
Total, Climate Forcing	**-1,149**
Climate Change Modeling	
▪ Climate Modeling - Support for the Climate Change Prediction Program-ARM Parameterization Testbed will be scaled back because the increased funding for ARM science will allow it to cover most of the costs of testing the performance of parameterization schemes (e.g., cloud models) in climate models. In addition, the Climate Change Prediction Program investments will be scaled back and reduced to projects that complement SciDAC projects, thus focusing on analysis of long-term observational data and climate model simulation data sets to yield new insights into climate variability and change. Support for university grants that complement the current SciDAC computational research for climate modeling will be reduced because the SciDAC projects at DOE labs are considered adequate to meet existing programmatic needs.	-1,505
Climate Change Response	
▪ Ecosystem Function and Response decreases. Support for major experimental studies to quantify the response of terrestrial ecosystems to climatic and atmospheric changes will be reduced to support higher priority programs within BER. This will delay the initiation of new experimental studies and the production of data needed to produce and test models for simulating the response of some major ecological systems to climatic changes.	-1,351

	FY 2007 vs. FY 2006 ($000)
▪ FACE user facility funding decreases as the upgrade of the facility has been completed.	-396
▪ Integrated Assessment is held at FY 2006 levels.	-58
Total, Climate Change Response	**-1,805**
Climate Change Mitigation	
▪ Carbon Sequestration research - Ocean Carbon Sequestration research is concluded. Because of the adverse effects of deep ocean disposal of CO_2 on ocean biology and ecology, and the ineffectiveness and potential risks to the ecology of the ocean of large-scale iron fertilization, neither ocean sequestration option is currently considered environmentally acceptable or viable. Hence, there is no need for continuing research on ocean sequestration as a potential option for helping to mitigate the increase in atmospheric CO_2 concentrations.	-1,933
SBIR/STTR	
▪ SBIR/STTR reduced due to research program reductions.	-228
Total Funding Change, Climate Change Research	**-6,620**

Environmental Remediation

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Environmental Remediation			
Environmental Remediation Sciences Research	61,435	52,270	50,479
Facility Operations	39,140	39,190	44,453
SBIR/STTR	—	2,284	2,264
Total, Environmental Remediation	100,575	93,744	97,196

Description

The mission of the Environmental Remediation subprogram is to deliver the scientific knowledge, technology, and enabling discoveries in biological and environmental research needed to underpin the Department of Energy's mission for environmental quality.

Benefits

The fundamental research supported in this subprogram will reduce the costs, risks, and schedules associated with the cleanup of the DOE nuclear weapons complex; extend the frontiers of methods for remediation; discover the fundamental mechanisms of contaminant transport in the environment; and develop cutting edge molecular tools for investigating 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.

Supporting Information

Research priorities for the Environmental Remediation Sciences subprogram include defining and understanding the processes that control contaminant fate and transport in the environment and providing opportunities for use, or manipulation of natural processes to alter contaminant mobility. 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 EMSL budget is to be increased to maintain operations at full capacity. Reductions in Environmental Remediation Sciences research funding will result in the termination of research on high-level waste, including waste storage tanks. Currently funded projects in this area of research will be terminated. This will eliminate SC efforts to develop science-based alternatives for the closure and long-term stewardship of high-level waste and waste storage tanks. As a result of ongoing prioritization by BER, research emphasis within the Environmental Remediation Sciences subprogram is being focused on issues of subsurface cleanup. The nature of the scientific questions and the timelines associated with those questions are better suited to the basic science mission of Environmental Remediation Sciences than are those of high level waste.

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 the 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.

The Environmental Remediation 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 clean-up 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 recently integrated 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."

Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes.

FY 2005 Accomplishments

- Field Research Leads to Advances in Understanding the Role of Microbes in Contaminant Fate & Transport: Following recommendations of its BERAC subcommittee and a Committee of Visitors, the Environmental Remediation Sciences subprogram is expanding field-based research. Current field research helped to establish the potential for subsurface microorganisms to immobilize contaminant metals and radionuclides *in situ*. Researchers at the Old Rifle Uranium Mill Tailings Remedial Action (UMTRA) site are using advanced DNA and mRNA techniques to link gene expression of subsurface metal-reducing bacteria to the bioremediation of uranium. The results show that increases in gene expression levels can be used to quantitatively model microbial metabolism *in situ*. Thus, gene expression techniques may be used to better design natural and enhanced bioremediation technologies. Researchers at the Hanford site have successfully tested a commercially available product that enhances the activity of metal-reducing microorganisms to immobilize chromium in the subsurface. Work at the Field Research Center (FRC) at the Oak Ridge site is demonstrating an *in situ* remediation process that manipulates subsurface conditions to make uranium available for consequent reduction and immobilization by microorganisms. Sequencing efforts at the JGI will provide the first example of a complete set of sequenced genomes of a complex subsurface microbial community (Oak Ridge FRC). These results should allow a comprehensive description of the genetic potential of a subsurface microbial community. The incorporation of seismic and electrical surveys during *in situ* stimulation of microbial communities indicated that stimulated changes in the subsurface could be monitored over time by surface measurements, markedly reducing the need for recovery of expensive cored material from the subsurface.

- Grand Challenges in Environmental Molecular Sciences: The Environmental Remediation Sciences subprogram, in collaboration with Pacific Northwest National Laboratory (PNNL), has implemented a Grand Challenges concept at the Environmental Molecular Sciences Laboratory (EMSL). EMSL has launched two scientific Grand Challenges that will bring together some of the world's leading environmental molecular scientists to study fundamental questions in membrane biology and biogeochemistry that underlie issues critical to DOE and the Nation. Grand Challenges engage multi-institutional and multidisciplinary teams to address complex, large-scale scientific and engineering problems with broad scientific and environmental or economic impacts by using multiple experimental and computational capabilities within the EMSL. Scientists from more than twenty universities and research institutions worldwide are focused on the first EMSL Grand Challenges in biogeochemistry and membrane biology. The EMSL Grand Challenge in Biogeochemistry is led by PNNL scientists and is examining a key feature of the interface between the biosphere and the geosphere: how microorganisms regulate energy, electron and proton fluxes between cells and mineral solids present in soils and subsurface sediments. The research is expected to have broad implications for contaminant transport in the environment and remediation, corrosion, mineral formation and for understanding global biogeochemical cycles. The EMSL Grand Challenge in Membrane Biology is led by university scientists and is directed toward the fundamental changes that occur in membrane processes in Cyanobacteria due to changes in the surrounding environment. This investigation of one of the most abundant groups of microorganisms on earth is expected to make significant contributions to the harvesting of solar energy, global carbon sequestration, nutrient metal acquisition, and hydrogen production in marine and freshwater ecosystems.
- High-level Waste: The high-level radioactive waste program continued with 75 projects in FY 2005, addressing key scientific issues in characterization of tank wastes, separation and processing of components of the wastes that have been removed from the storage tanks, and assessing the stability of waste storage forms. This research already demonstrated direct value to the Environmental Management (EM) cleanup program through, for example, reduction of foaming problems that disrupted waste processing, and through development of novel extraction agents for removal of strontium from waste mixtures. Each of these accomplishments resulted in large savings of both cost and time by solving otherwise intractable problems. Current research is directed at overcoming a number of major obstacles in the cleanup process, including finding means of reducing the volumes of alkaline tank waste and development of green separation technologies that minimize residue from processing of high level radioactive wastes.
- New Efforts in the Environmental Molecular Sciences: Researchers at the DOE/National Science Foundation (NSF) co-funded Environmental Molecular Science Institutes (EMSIs) are providing fundamental insights into reactions occurring at the water-mineral interface and within microbial biofilms at mineral surfaces, issues critical to prediction of contaminant fate and transport as well as to development of new remediation concepts. Researchers at the Stanford University EMSI are continuing to probe the fundamental structure of liquid water. Previous research by this group was recently featured as one of the top ten science stories of 2004 by *Science* magazine. Investigations at the Penn State University EMSI are documenting the rates of environmentally important reactions occurring across a variety of scales within the subsurface. An American Chemical Society symposium led by Penn State EMSI researchers highlighted the issues involved in scaling geochemical reactions occurring at the sub-nanometer scale to processes occurring at the field scale (meters to kilometers). These researchers also have developed a computer model that begins to describe changes in subsurface pore structure due to mineral precipitation in groundwater—a key issue for contaminant immobilization technologies. Researchers at the Stony Brook University EMSI

continue to probe geochemical reactions that lead to the sequestering of contaminants, such as arsenic and radionuclides, at mineral surfaces and immobilization of contaminants in subsurface environments.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Environmental Remediation Sciences Research	**61,435**	**52,270**	**50,479**
▪ **Environmental Remediation Sciences Research**	**56,892**	**45,727**	**43,936**

The Environmental Remediation Sciences Research activity will address critical questions of fundamental environmental remediation science at the interfaces of biology, chemistry, geology and physics. Research results will 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 research activity will support a tiered set of 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. The overall focus and integration strategy will center on field research since the ultimate goal of the Environmental Remediation Sciences subprogram is the development of science-based remediation strategies and a conceptual understanding of environmental processes that can be implemented to solve existing environmental problems. 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, environmental, and geophysical parameters associated with the behavior of contaminants in the environment. This broad-based, tiered approach responds to recommendations of the BERAC Environmental Remediation Sciences subcommittee and a Committee of Visitors review.

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. Funding reductions in FY 2006 have delayed plans to initiate new field-based research aimed at achieving that goal. These new efforts are now planned for initiation in FY 2007 and will complement ongoing work at the Oak Ridge Field Research Center (FRC), the Old Rifle UMTRA site and the Hanford site. This expanded field-based research will allow scientists to evaluate concepts and hypotheses under a variety of geochemical 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 clean-up mission. These new activities also will emphasize the need for coordination between experimentation and computer simulation as critical components of both experimental design and model development.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

The expanded field research activities will be used to evaluate and validate the results of laboratory-based science and predictive modeling efforts.

This newly integrated research activity will continue to foster interdisciplinary research and be more responsive to new knowledge and to advanced computational and analytical tools that emerge from research at the EMSL, the synchrotron light sources, and from within the GTL program in support of DOE's clean-up mission.

BER participation in SciDAC will provide an opportunity for subsurface and computational scientists to develop and improve methods of simulating subsurface reactive transport processes on "discovery class" computers. 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.

In FY 2007 reductions in Environmental Remediation Sciences subprogram research funding will result in termination of research in high-level waste, including waste in storage tanks. Currently funded projects in this area of research will be terminated. This will eliminate SC efforts to develop science-based alternatives for the closure and long-term stewardship of high-level waste and waste storage tanks. As a result of ongoing prioritization by BER, research emphasis within the Environmental Remediation Sciences subprogram is being focused on issues of subsurface cleanup. The nature of the scientific questions and the timeliness associated with those questions are better suited to the basic science mission of Environmental Remediation Sciences than are those of high level waste. The Environmental Remediation Sciences research subprogram will narrow its research efforts to focus on subsurface science in support of its long-term measure for environmental cleanup.

▪ **General Purpose Equipment (GPE)**..............	**1,659**	**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 supports multi-purpose research.

▪ **General Plant Projects (GPP)**........................	**2,884**	**6,140**	**6,140**

GPP funding is continued for minor new construction, other capital alterations and additions, and for buildings and utility systems, such as replacing piping in 30- to 40-year old buildings, modifying and replacing roofs, and HVAC upgrades and replacements. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and 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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Facility Operations	**39,140**	**39,190**	**44,453**
▪ **EMSL Operating Expenses**	**31,958**	**33,702**	**35,649**

The EMSL is a scientific user facility located at the Pacific Northwest National Laboratory focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are used for: staff support for users; maintenance of instruments and buildings; utilities; environment, 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 2007 EMSL operations funding is increased to enhance user facility operations and increase services to users.

▪ **General Plant Projects (GPP)**	**3,200**	**—**	**—**

The GPP (TEC $4,450,000) for EMSL's Molecular Science Computing Facility (MSCF) adds approximately 4,000 sq. ft of additional space. The additional MSCF space is needed to meet the demand for new data storage systems due to the volume of data being generated by EMSL's high-throughput mass spectrometer, NMR, and other systems. Design of this project is in progress and is planned for completion in FY 2006.

▪ **Capital Equipment**	**3,982**	**5,488**	**8,804**

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 2007 increased capital equipment funds will be used to upgrade and refresh critical analytical capabilities in the areas of surface analytics (e.g., x-ray spectroscopy, Auger electron spectroscopy, secondary ion spectroscopy); increase capacity and throughput in proteomics (additional mass spectrometers) and high-field nuclear magnetic resonance spectroscopy (additional conventional and customized cryoprobes and consoles); increase electronic data storage capacity for data archiving of spectroscopic and proteomic output, and refurbish and replace aging support equipment (e.g,. turbopumps and laser systems, cryostats).

SBIR/STTR	**—**	**2,284**	**2,264**

In FY 2005 $2,316,000 and $278,000 were transferred to the SBIR and STTR programs, respectively. FY 2006 and FY 2007 amounts are the estimated requirements for continuation of the programs.

Total, Environmental Remediation	**100,575**	**93,744**	**97,196**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Environmental Remediation Sciences Research	
▪ Reductions in Environmental Remediation Sciences research funding will terminate research on high-level waste, including waste storage tanks. Currently funded projects in this area will be terminated. This will eliminate SC efforts to develop science-based alternatives and understanding for the closure and long-term stewardship of high-level waste and waste storage tanks. As a result of ongoing prioritization by BER, research emphasis within the Environmental Remediation Sciences subprogram is being focused on issues of subsurface cleanup. The nature of the scientific questions and the timelines associated with those questions are better suited to the basic science mission of Environmental Remediation Sciences than are those of high level waste.	-1,791
Facility Operations	
▪ In FY 2007, EMSL operations funding is increased to maintain existing levels of user service	+1,947
▪ In FY 2007, funding for EMSL capital equipment increases. Increased capital equipment funds will be used to upgrade and refresh critical analytical capabilities in the areas of surface analysis techniques; functional genomics analysis and high-field nuclear magnetic resonance spectroscopy. These funds will also increase electronic storage capacity within EMSL for archiving spectroscopic and functional genomics data by allowing refurbishment or replacement of aging archival support equipment	+3,316
Total, Facility Operations	**+5,263**
SBIR/STTR	
▪ SBIR/STTR decreases with reduction in research.	-20
Total Funding Change, Environmental Remediation	**+3,452**

Medical Applications and Measurement Science

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Medical Applications and Measurement Science			
Medical Applications	117,858	138,576	13,608
Measurement Science	4,066	—	—
SBIR/STTR	—	3,987	392
Total, Medical Applications and Measurement Science	121,924	142,563	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 critical 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, that improve quality of life for affected patients.

Supporting Information

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

Today the 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' unique 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 (e.g., the artificial retina) 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. DOE and NIH also organize and sponsor workshops in common areas of interest, for example: a joint workshop on Optical and X-ray Imaging, and Nanomedicine. Members of the Medical Sciences 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). Program 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. This program was examined as part of a BERAC review of the entire BER program in FY 2001. The next scheduled comprehensive review of the Medical Applications and Measurement Science subprogram by a BERAC COV will be in FY 2006.

FY 2005 Accomplishments

- Progress in Helping the Blind to See: The DOE Artificial Retina Program (ORNL; SNL; LANL; ANL; LLNL; University of Southern California; UC, Santa Cruz; North Carolina State; and Second Sight Corp.) has made significant progress in the roadmap to developing a device to restore vision to people suffering from retinal blindness. Six blind patients have been implanted with a 16-electrode device. They are now able to recognize moving light, discriminated light from dark, and discern large objects. A sixty electrode device is completing animal testing and will be implanted in 2006. Design for a 256 electrode device has been completed and construction is underway.
- Smaller, More Versatile PET Scanners: BNL has completed a prototype mobile PET scanner ("the rat cap") which will record images in the awake animal. The mobile PET will be able to acquire positron-generated images in the absence of anesthesia-induced coma and correct for motion of the animal. The long-term goal is to develop PET instrumentation able to diagnose neuro-psychiatric disorders in children.
- Ultra-high performance Hybrid Imaging Instrumentation Developed: Scientists at the Thomas Jefferson National Accelerator Facility have built a small-animal imaging device that is an ultra-high performance gamma camera detector combined with an optical detector. The instrument is a high resolution hybrid tomographic system for small animals and is capable of producing 3 dimensional images of the distribution of both radiotracers and fluorescent/bioluminescent molecules. It will achieve a remarkable spatial resolution of under 0.5mm.
- Highest Resolution PET scanner Developed: Scientists at the LBNL have developed the world's most sensitive PET scanner. The instrument is 10-times more sensitive than a conventional PET scanner. The instrument became operational in 2005.
- Imaging Gene Expression in Cancer Cells: Images of tumors in whole animals which detect the expression of three cancer genes were accomplished for the first time by investigators at Thomas Jefferson University and the University of Massachusetts Medical Center. The three cancer genes probed were CCND1, MYC, and KRAS. This advanced imaging technology will lead to the detection of cancer in human using cancer cell genetic profiling.
- Modeling Radiation Damage to the Lung: Treatment of thyroid disease and lymphomas using radioisotopes can cause disabling lung disease. Investigators at Johns Hopkins University have developed a Monte Carlo model that can be used to determine the probability of lung toxicity and be

incorporated into a therapeutic regimen. This model will optimize the dose of radioactivity delivered to cancer cells and avoid untoward effects on the lung.

- New radiopharmaceuticals with Important Clinical Applications: The DOE radiopharmaceutical science program has developed a number of innovative radiotracers for the early diagnosis of neuro-psychiatric illnesses. Three agents were developed at the University of California at Irvine. One agent localizes to beta amyloid in the brain plaques found in Alzheimer's Disease. A new nicotine receptor imaging agent, 18F-nifrolidine has a high affinity for targets in the diagnosis and understanding of Alzheimer's Disease and schizophrenia. A new serotonin receptor imaging agent, 18F-mefway, will be useful in the diagnosis of depression and anxiety disorders.
- Rapid Preparation of Radiopharmaceuticals for Clinical Use: The preparation of radiohalogenated pharmaceuticals for use in Nuclear Medicine is a formidable task. The DOE sponsored program at the University of Tennessee has developed a totally new method for preparing radiopharmaceuticals by placing a boron-based salt at the position that will be occupied by the radiohalogen. The salt is simply mixed with a radiohalogen and the desired product decanted or filtered from the salt-like starting materials. The method has been used to prepare a variety of cancer-imaging agents
- Brain Pathway in Obesity Uncovered: Using highly-specific radiotracers as molecular probes, BNL researchers discovered a deficiency in the reward circuits in the brains of obese individuals that are similar to abnormalities observed in drug abusers. This suggests that obese individuals are overeating to compensate for a deficiency in the dopamine system in the brain which regulates the reward system. These results may be useful in developing strategies for the treatment of obesity.
- Understanding Nicotine Addiction: BNL researchers have developed a new radiopharmaceutical agent to image the brain nicotine system and have used this tracer to show striking images of nicotine binding sites in the human brain. The new radiotracer is being used to understand the molecular basis of nicotine addiction and to devise smoke-ending strategies.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Medical Applications	**117,858**	**138,576**	**13,608**
▪ **Medical Applications**	**38,735**	**13,480**	**13,608**

In FY 2007, BER supports 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, 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. BER utilizes the resources of the National Laboratories in material sciences, engineering, microfabrication and microengineering to fund development of unique neuroprostheses and continue to develop construction of an artificial retina to restore sight to the blind. DOE's clinical goal for the artificial retina project is to develop the technology and construct a

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

1,000+ electrode intraocular device that will allow a blind person to read large print, recognize faces, and move around without difficulty.

The research activities in this subprogram are principally carried out at National Laboratories and are selected through competitive and merit-reviewed processes.

▪ **Congressionally Directed Activities**	**79,123**	**125,096**	**—**

Congressional direction was provided in FY 2005 for a science building at Waubonsee Community College in Illinois; digital playback hardware and software for Recording for the blind and dyslexic; All Children's Hospital in Florida; Eckerd College in Florida; Applied Research and Technology Park electrical and communication infrastructure improvements in Springfield, Ohio; a Multiple Sclerosis, Alzheimer's, Parkinson's, Lou Gehrig's Imaging System at the Cleveland Clinic in Ohio; Duchenne Muscular Dystrophy research-related equipment at Children's National Medical Center in the District of Columbia; Duchenne Muscular Dystrophy research-related equipment at the University of Washington-Seattle; the Northeast Regional Cancer Center in Scranton, Pennsylvania; Ohio State University for environmental research in cooperation with Earth University; the University of Akron, Ohio, Polymer Center; the Ohio Northern University, Ada, Ohio, Science and Pharmacy Building; the Alabama A&M University; University of Texas at Arlington optical medical imaging equipment; the Missouri Alternative and Renewable Energy Technology Center, Crowder College; the San Antonio, Texas, Cancer Research and Therapy Center; the University of South Alabama Cancer Center; the Virginia Commonwealth University Massey Cancer Center; the Saint Francis Hospital, Delaware, Cardiac Catheterization Lab; the Jacksonville University Environmental Science Center; the Houston, Texas, Alliance for Nanohealth; the Virginia Science Museum; the Polly Ryon Memorial Hospital, Texas; the St. Thomas University Minority Science Center, Miami, Florida; Project Intellicare, Roseville, California; the Virginia Polytechnic Institute Center for High-Performance Learning Environment; Georgia State University; the Michigan Research Institute for life science research; the University of Arizona Environment and Natural Resources Phase I1 Facility; the Children's Hospital of Illinois ambulatory care project; the Loma Linda University, California, Medical Center synchrotron expansion; the University of Dubuque, Iowa, Environmental Science Center; the Ball State University, Indiana, Bioenergetics Research Initiative; the Clearfield Area School District, Pennsylvania, Energy Initiative; Digital Cardiology equipment at Children's Hospital and Research Center, Oakland, California; the National Childhood Cancer Foundation; the Roswell Park Cancer Institute, New York, Center for Genetics and Pharmacology; Bucknell University, Pennsylvania, Materials Science Laboratory; the Science Center at Mystic Seaport, Connecticut; the Saratoga Hospital, New York, radiation therapy center; the San Joaquin Community Hospital, Bakersfield, California; the Syracuse University, New York, Environmental Systems Center; the University of Tennessee Sim Center; the St. Mary's Hospital, Kankakee, Illinois; the Derby Center for Science and Mathematics at Lyon College in Arkansas; the Rush Presbyterian St. Lukes Medical Center in Illinois; Medical Research and Robotics at the University of Southern California; the Advanced Building Efficiency Testbed at Carnegie Mellon University; DePaul University Biological Sciences; the Philadelphia Educational Advancement Alliance; Northwestern University Institute of Bioengineering and Nanoscience in Medicine; the Rensselaer Polytechnical Institute Center for Bioscience; St. Peter's Biotechnical Research in New Jersey; the Berkshire Environmental Center in Massachusetts; the Center for the Environment at the University of

(dollars in thousands)		
FY 2005	FY 2006	FY 2007

Massachusetts; technical upgrades at St. Joseph Hospital in Arizona; the Center for Science at the University of San Francisco in California; Augsburg College in Minnesota; the Bronx Community Center for Sustainable Energy; Marquette General Hospital in Marquette, Michigan; the Illinois-Indiana Super-Grid Program connecting Argonne National Laboratory and Purdue and Notre Dame Universities; the Purdue Calumet Water Environmental Institute; the Multi-Discipline Engineering Institute at Notre Dame in Indiana; the Energy Efficiency Project at Valparaiso University in Indiana; the Mental Illness and Neuroscience Discovery Institute in New Mexico; Military Spirit in New Mexico; the Academic Center Sustainable Design Project at St. Francis College, New York; the University of Louisville Pediatric Clinical Proteomic Center; the University of Louisville Institute for Advanced Materials; the Advanced Bioreactor located in Butte, Montana; to expand the Center for Integrated and Applied Environmental Toxicology at the University of Southern Maine; the University of Tennessee Cancer Institute; St. Jude Children's Research Hospital in Tennessee; the Huntsman Cancer Institute; the Mega-Voltage Cargo Imaging Development Applications for the Nevada Test Site; the California Hospital Medical Center PET /CT Fusion Imaging System; the Luci Curci Cancer Center Linear Accelerator; Project Intellicare in California; the University Medical Center in Las Vegas, Nevada; the Southern California Water Education Center; Live Cell Molecular Imaging System at the University of Connecticut; the St. Francis Hospital Wilmington, Delaware, MRI and Cardiac Catherization Laboratory; the University of Delaware for the Delaware Biology Institute; the University of Nevada-Las Vegas School of Public Health; the Latino Development and Technology Center; the Swedish American Health Systems; DePaul University Chemistry Lab Renovation Project; the Edward Hospital Cancer Center; the Mary Bird Perkins Cancer Center; the Morgan State University Center for Environmental Toxicology; the Suburban Hospital in Montgomery County, Maryland; the University of Massachusetts at Boston Multidisciplinary Research Facility and Library; the Martha's Vineyard Hospital; the Nevada Cancer Institute; the Mercy Hospital Grayling, Michigan Rural Healthcare Advancement Initiative; the Health Sciences Complex at Creighton University; the Hackensack University Medical Center Women and Children's Pavilion; the Kennedy Health System Linear Accelerator; the University of Buffalo Center of Excellence in Bioinformatics; the Hospital for Special Surgery National Center for Musculoskeletal Research; the New University in New York City; the Radiochemistry research facility at the University of Nevada-Las Vegas; the Hauptman-Woodward Medical Research Institute; the Vermont Institute of Natural Science; and the Tahoe Center for Environmental Services; Southwest Regional Cooling, Heating and Power and Bio-Fuel Application Center; Upgrade Chemistry Laboratories at Drew University, New Jersey; University of Texas Southwestern Medical Center, University of Texas at Dallas Metroplex Comprehensive Imaging Center; Fire Sciences Academy in Elko, Nevada for purposes of capital debt service; and the Desalination plant technology program at UMR.

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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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; 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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 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.

Measurement Science	**4,066**	**—**	**—**

Measurement Science Research is integrated with Medical Applications in FY 2006. There is not a separate request for Measurement Science Research in FY 2007.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
SBIR/STTR	**—**	**3,987**	**392**

In FY 2005 $3,066,000 and $368,000 were transferred to the SBIR and STTR programs, respectively. FY 2006 and FY 2007 amounts are the estimated requirements for continuation of the programs.

	FY 2005	FY 2006	FY 2007
Total, Medical Applications and Measurement Science	**121,924**	**142,563**	**14,000**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Medical Applications	
▪ Medical Applications Research is held near FY 2006 levels.	+128
▪ One-time Congressionally directed projects are completed.	-125,096
Total, Medical Applications	**-124,968**
▪ **SBIR/STTR**	
SBIR/STTR is decreased with the decreased research funding.	-3,595
Total Funding Change, Medical Applications and Measurement Science	**-128,563**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Construction			
Project Engineering and Design	9,920	—	—

Description

Facilities to support Genomics: GTL research under the Biological and Environmental Research (BER) program.

Benefits

The proposed Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags, would surmount a principal roadblock to whole-system analysis by implementing high-throughput production and characterization of microbial proteins. It also would generate protein-tagging reagents for identifying, tracking, quantifying, controlling, capturing, and imaging individual proteins and molecular machines in living systems.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Project Engineering and Design**	**9,920**	**—**	**—**

Project Engineering and Design (PED) funding supports the proposed Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags was appropriated in FY 2005.

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
General Plant Projects	6,084	6,140	6,140
Capital Equipment	18,821	11,016	26,121
Total Capital Operating Expenses	24,905	17,156	32,261

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Unappro-priated Balance
PED, 05-SC-004 Production and Characterization of Proteins and Molecular Tags	9,920	—	9,920	—	—	—
Total, Construction			9,920	—	—	

High Energy Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
High Energy Physics					
Proton Accelerator-Based Physics	391,360	392,093	-16,994[ab]	375,099	376,536
Electron Accelerator-Based Physics	135,001	132,822	-15,789[ab]	117,033	117,460
Non-Accelerator Physics	55,590	38,589	+9,427[ab]	48,016	59,271
Theoretical Physics	50,065	49,103	-913[ab]	48,190	52,056
Advanced Technology R&D	90,145	111,326	+17,030[ab]	128,356	159,476
Subtotal, High Energy Physics	722,161	723,933	-7,239	716,694	764,799
Construction	745	—	—	—	10,300
Total, High Energy Physics	722,906[c]	723,933	-7,239	716,694	775,099

Public Law Authorizations:

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

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 HEP program is to understand how our universe works. 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. HEP underpins and advances the DOE missions and objectives through the development of key technologies and trained manpower needed to work at the cutting edge of science.

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006, as follows: Proton Accelerator-Based Physics ($-3,921,000); Electron Accelerator-Based Physics ($-1,328,000); Non-Accelerator Physics ($-386,000); Theoretical Physics ($-491,000); and Advanced Technology R&D ($-1,113,000).

[b] Reflects a reallocation of funding in accordance with H.Rpt. 109-275, the conference report for the Energy and Water Development Appropriations Act, 2006, as follows: Proton Accelerator-Based Physics ($-13,073,000); Electron Accelerator-Based Physics ($-14,461,000); Non-Accelerator Physics ($+9,813,000); Theoretical Physics ($-422,000); and Advanced Technology R&D ($+18,143,000).

[c] Total is increased by $4,500,000 for a reprogramming from Science Laboratories Infrastructure and is decreased by $5,936,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $16,105,000, which was transferred to the SBIR program; and $1,933,000, which was transferred to the STTR program.

Benefits

HEP supports 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 indispensable 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 Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of its mission) plus seven general goals that tie to the strategic goals. The HEP program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

The HEP program has one program goal which contributes to General Goal 5 in the "goal cascade":
Program Goal 05.19.00.00: 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 Program Goal 05.19.00.00 (Explore the Fundamental Interactions of Energy, Matter, Time and Space)

The High Energy Physics (HEP) program contributes to this goal by advancing our understanding of the basic constituents of matter, deeper symmetries in the physical laws of particles at high energies, dark energy and dark matter, and the possible existence of other dimensions of space. HEP uses particle accelerators and very sensitive detectors to study fundamental interactions at the highest possible energies. Because particle physics is fundamentally involved in 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 mountain tops, 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. At the same time, the HEP program can shed new light on other mysteries of the cosmos, uncovering the mysterious dark matter that holds galaxies together and the even more mysterious dark energy that is stretching space apart; explaining why there is any matter in the universe at all; and showing how the tiniest constituents of the universe play a leading role in shaping its birth, growth, and ultimate fate. Our goals in FY 2007 address all of these challenges. The FY 2007 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 accelerator operations at SLAC through the construction of the Linac Coherent Light Source (LCLS) and the transition of that facility 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 5.19.00.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space (High Energy Physics)	722,906	716,694	775,099

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 05.19.00.00 (Explore the Fundamental Interactions of Energy, Matter, Time and Space)					
All HEP Facilities					
Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. [Met Goal]	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. [Met Goal]	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. [Met Goal]	Maintain and operate HEP facilities such that unscheduled downtime is 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					
Deliver data as planned (80 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned (225 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned within 20% of the baseline estimate (240 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned within 20% of the baseline estimate (390 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned within 20% of the baseline estimate (675 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.
				Deliver data as planned within 20% of the baseline estimate ($1x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.[a]	Deliver data as planned within 20% of the baseline estimate ($1.5x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.[a]
Electron Accelerator-Based Physics/Facilities					
Increase the total data delivered to BaBar at the SLAC B-factory by delivering 35 fb-1 of total luminosity. *[Met Goal]*	Increase the total data delivered to BaBar at the SLAC B-factory by delivering 45 fb-1 of total luminosity. *[Goal Not Met]*	Deliver data as planned within 20% of baseline estimate (45 fb-1) to the BaBar detector at the SLAC B-factory. *[Met Goal]*	Deliver data as planned within 20% of baseline estimate (50 fb-1) to the BaBar detector at the SLAC B-factory. *[Met Goal]*	Deliver data as planned within 20% of the baseline estimate (100 fb-1) to the BaBar detector at the SLAC B-factory.	Deliver data as planned within 20% of the baseline estimate (150 fb-1) to the BaBar detector at the SLAC B-factory.
Construction/Major Items of Equipment					
Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. *[Met Goal]*	Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. *[Met Goal]*	Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. *[Met Goal]*	Maintain cost and schedule milestones for upgrades and new major 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.

[a] These annual targets are tracked and reported by the internal DOE performance management system, but are not currently tracked as PART measures.

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. 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 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 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 HEP program has incorporated feedback from OMB into the FY 2005 and FY 2006 Budget Requests and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the HEP program a relatively high 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 found that HEP has developed a limited number of adequate performance measures which are continued for FY 2007. 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—see Advisory and Consultative Activities below) 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 Report. In response to PART findings, HEP 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. The COV report is available on the web (http://www.science.doe.gov/hep/HEPAPCOVReportfinal.pdf). Within 30 days of receiving the report, HEP developed an action plan to respond to its findings and recommendations. This action plan is also available on the web at (http://www.sc.doe.gov/hep/OfficeofHEPResponsetoCOVreport.shtm). The Particle Physics Project Prioritization Panel (P5—see Advisory and Consultative Activities) also submitted its first report in September 2003, and a revised update in August 2004. These reports are available on the web (http://www.science.doe.gov/hep/hepap_reports.shtm). HEP plans for future facilities, based upon that input, are reflected in this Budget Request.

For the FY 2007 Budget, OMB has developed PARTWeb—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the website http://ExpectMore.gov and will improve public access to PART assessments and follow up actions. For 2006 there are three actions for High Energy Physics.

- Implementing the recommendations of past and new external assessment panels, as appropriate.
- Developing a strategy and implementation plan for particle accelerator research and development, including a potential international linear collider.
- Engaging 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.

HEP values input from outside the High Energy Physics community and is working with the National Academies to develop a prioritized long term plan. HEP also takes seriously its role in supporting accelerator R&D for the Department, and will initiate a planning process, with community input, to develop a strategy for accelerator R&D within DOE that incorporates the challenges of a potential international linear collider. HEP is actively working to implement recommendations from expert panels as appropriate.

Improvements are posted at http://www.sc.doe.gov/measures/FY06.html.

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 deeper theory that can explain these new phenomena. A revolution in particle physics, and in our understanding of the universe in which we live, is coming.

Questions

A worldwide program of particle physics research is underway to explore the new scientific landscape. A recent HEPAP subpanel report, *Quantum Universe*, summarized the key questions:

- Are there undiscovered principles of nature: new symmetries, new physical laws?

  The quantum ideas that so successfully describe familiar matter fail when applied to cosmic physics. The problem might be solved by the appearance of new forces and new particles signaling the discovery of new symmetries—undiscovered principles of nature's behavior.

- 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. Dark energy might be similar to the Higgs field, a quantum field representing "vacuum energy" that exists throughout space.

- Are there extra dimensions of space?

  Current theories that attempt to reconcile quantum ideas with gravity predict the real existence of undiscovered dimensions of space that might explain much of the observed complexity of particle physics. The discovery of extra dimensions would be an epochal event in human history. It would change our understanding of the birth and evolution of the universe. If some of these extra dimensions are as large as some theories predict, the force of gravity could increase at short distances. This increase could be seen at the Large Hadron Collider (LHC) by production of "mini-black-holes" and a whole new spectrum of particle states.

- Do all the forces become one?

  At the most fundamental level all forces and particles in the universe are thought to be related, with all the forces thought to be manifestations of a single unified force. Such a unified theory of all forces was Einstein's great dream. Recent theoretical efforts have made progress toward this goal.

- Why are there so many kinds of particles?

  Why do three families of particles exist, and why do their masses differ so dramatically? Patterns and variations in the families of elementary particles suggest undiscovered principles that tie together the quarks and leptons of the Standard Model.

- What is dark matter? How can we make it in the laboratory?

  Most of the matter in the universe is unknown dark matter; probably particles produced in the Big Bang that interact very rarely with normal matter. These particles may have a small enough mass to be produced and studied at accelerators, or detected "au naturel" in cosmic rays, using ultra-sensitive detectors.

- What are neutrinos telling us?

  Of all the known particles, neutrinos are the most mysterious. They played an essential role in the evolution of the universe, and their tiny but nonzero masses may imply new physics and unification at very high energies.

- How did the universe come to be?

  According to current cosmological ideas, our universe may have begun with a disturbance of space-time, followed by a burst of inflationary expansion of space itself. This model of the cosmos is called the "Big Bang." Following inflation, the universe cooled, allowing the formation of stars, galaxies, and ultimately life. A fuller understanding of the evolution of the universe requires breakthrough in our understanding of quantum physics and quantum gravity.

- What happened to the antimatter?

  The universe now is made almost entirely of matter, with very little antimatter, although it is thought the Big Bang must have produced the same amounts of matter and antimatter, because we find this to be the case in high energy collisions in the laboratory. How then did the asymmetry arise?

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 2005, the DOE HEP program provided about 90% of the federal support for high energy physics research in the nation; the NSF provides most of the remaining support. The program is responsible for: planning and prioritizing all aspects of supported research; conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders; supporting core university and national laboratory programs; and maintaining a strong infrastructure to support high energy physics research.

Advisory and Consultative Activities

To ensure that resources are allocated to the most scientifically promising experiments, 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), will advise DOE and NSF on specific questions concerning the U.S. neutrino program. 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.

The National Academy of Sciences was chartered by Congress 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. It conducted a "science assessment and strategy for…research at the intersection of astronomy and physics," which was published in 2003 as *Connecting Quarks with the Cosmos.* A new study is being carried out for the DOE and the NSF by the NRC in 2005-2006, which will assess and prioritize opportunities in high energy physics and the tools needed to realize them in the next 15 years.

DOE was part of the National Science and Technology Council's (NSTC) Interagency Working Group on the Physics of the Universe. In 2004, the Working Group released a strategic plan for how the agencies will address the recommendations from the *Connecting Quarks with the Cosmos* report. Included in this plan are specific recommendations for the DOE to work together with the NSF and NASA to develop investments in emerging areas including dark energy, dark matter, and neutrino physics.

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 provides review and oversight for its research portfolio. All university research proposals are subjected to an intensive and multistage review process to ensure high quality research and an appropriate mix of experiments in the national program. 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 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 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. 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 most recent such plan was submitted in January 2002 and presented a "roadmap" for the field, laying out the physics opportunities envisioned for the next 20 years. As part of this roadmap, the panel recommended that the highest priority of the U.S. program be a high energy, high-luminosity electron-positron linear collider to be built as a fully international effort. HEPAP further recommended that a vigorous long-term R&D program aimed toward future high energy research facilities be carried out with high priority within the HEP program.

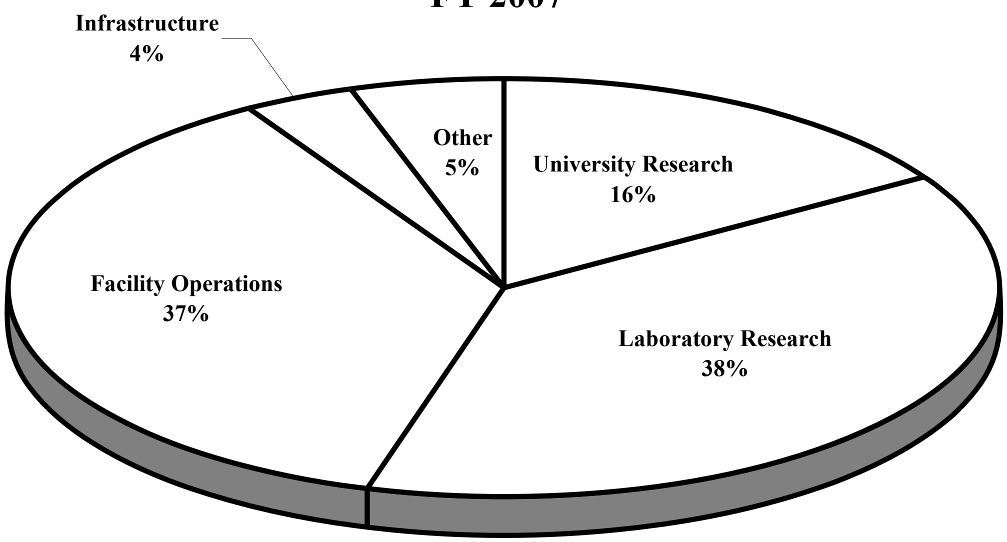
HEPAP also played an important role in advising the Director of the Office of Science on future facilities needed to address the most important HEP research questions for the next decade. Their recommendations on the scientific importance and technical readiness of several possible facilities were key elements in developing the Office of Science *Facilities Outlook*, published in 2003.

HEPAP also recommended a mechanism to update the roadmap and set 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 will play 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 37% of the FY 2007 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 38% is provided to laboratories, including multipurpose laboratories, in support of their HEP research and advanced technology R&D activities; 16% is provided for university-based physics research and advanced technology R&D; 4% for infrastructure improvements (general plant projects [GPP] and general purpose equipment [GPE]) and construction funds; and 5% 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 2007 budget request is focused on facility operations at Fermilab to advance research 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 at SLAC to advance research with the BaBar detector at the B-factory. Priority is also given to the ramp-up of the LHC research program in support of commissioning, operations and maintenance activities in anticipation of the start of the LHC physics program in 2007; and to a significant increase in R&D efforts focused in development of an International Linear Collider.

High Energy Physics Budget Allocation FY 2007



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 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 astrophysicists 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 2006 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. This is below the FY 2005 level-of-effort in most areas, so research managers will continue to exploit efficiencies and cost savings wherever possible. 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 and commerce where they are well-received. This highly trained human resource is part of the nation's economic and strategic strength. During FY 2005, 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 graduate students engaged in accelerator R&D. Typically, about 120 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 2007 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. Thus the longer-term HEP program supported by this request begins 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). Further, we have prioritized our current R&D efforts to select those which 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), and this request significantly advances the ILC R&D program. In making these decisions we have carefully considered the recommendations of 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 have been successfully carried out while still running the Tevatron collider at high efficiency. They were planned in detail using modern project management techniques and regularly reviewed by experts solicited by the Office of High Energy Physics. Much of the accelerator development effort 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 will put much higher demands on that set of accelerators. A new program of enhanced maintenance, operational improvements, and equipment upgrades is being developed to meet these higher demands, while continuing to run the accelerator. The plan will be managed and monitored in the same manner as the Run II luminosity improvements.

- In order to exploit the unique opportunity to expand the boundaries of our understanding of the origin of mass in the universe, a high priority is given to continued operations and infrastructure support for the B-factory at SLAC. Upgrades to the accelerator and detector are currently scheduled for completion in 2006, and B-factory operations will conclude no later than FY 2008. 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 the final year (2008) of B-factory running in Spring 2006.
- 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 the LHC physics program will continue to be a high priority of the HEP program.
- R&D in support of the ILC is doubled relative to FY 2006 to support a U.S. leadership role 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 a go/no go decision on a construction start for an international electron-positron linear collider near the end of the decade. In FY 2005 an international collaboration called the Global Design Effort (GDE) was organized to coordinate the R&D and design of a linear collider based on the superconducting radiofrequency technology.
- To provide a nearer-term future HEP program, and to preserve future research options, R&D for accelerator and detector technologies, particularly in the emerging area of neutrino physics, will continue at an increased level relative to FY 2006. Engineering design will begin on a new detector optimized to detect electron neutrinos, the Electron Neutrino Appearance (EνA) Detector, which will utilize the existing NuMI beam. Participation will begin in a reactor-based neutrino experiment and R&D for a high-intensity neutrino super beam facility and a double beta decay experiment will continue. These efforts are part of a coordinated neutrino program developed from an American Physical Society study and a joint HEPAP/NSAC subpanel review.
- In order to explore the nature of dark energy, support for R&D for the SNAP mission concept will be increased in FY 2007. SNAP will be a mission concept proposed for a potential interagency-sponsored experiment with NASA, the Joint Dark Energy Mission (JDEM). This experiment will provide important new information about the nature of dark energy that will in turn lead to a better understanding of the birth, evolution, and ultimate fate of the universe.
- In addition, to fully determine the nature of dark energy, independent and complementary measurements are scientifically advisable. In FY 2007, R&D will be done for ground facilities (in cooperation with NSF) and/or a variety of space-based facilities which could provide these measurements. Advice from the scientific community will be solicited to aid in selecting the particular concepts to be developed.

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 were 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 Chromo Dynamics (QCD) calculations, astrophysical simulations, accelerator simulation and modeling, and grid technology and deployment, as well as the FY 2007 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, NuMI beam line at Fermilab, and the B-factory at SLAC. The Tevatron Collider provided a total of 5,040 hours of beam time in FY 2005 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. The construction of NuMI has been completed and operation of the facility has begun, serving more than 250 researchers, of whom about two-thirds are U.S. researchers. The FY 2007 request will support facility operations at Fermilab that will provide ~4,560 hours of beams for the Tevatron Collider and for NuMI, including an allowance for increased power costs and fully funded upgrades. The B-factory provided a total of ~3,380 hours of beam time in FY 2005 for a research community of about 300 U.S. scientists in HEP and a comparable number of users from foreign countries. The FY 2007 request will support facility operations at SLAC that provide ~5,200 hours of beams for the B-factory, including an allowance for increased power costs.

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 2005	FY 2006	FY 2007
Tevatron Complex at Fermilab			
Optimal hours	5,040	4,320	4,560
Beam Hours - Tevatron	5,040	4,320	4,560
Unscheduled Downtime - Tevatron	<20%	<20%	<20%
Scheduled Hours - NuMI	N/A	4,320	4,560
Unscheduled Downtime - NuMI	N/A	<20%	<20%
Total Number of Users	2,160	2,125	2,160
B-factory at SLAC			
Optimal hours	4,550	5,200	5,200
Beam hours	3,380	5,200	5,200
Unscheduled Downtime	<20%	<20%	<20%
Total Number of Users	1,100	1,100	1,100

Construction and Infrastructure

Preliminary engineering design for a potential new construction project, the Electron Neutrino Appearance (EvA) Detector, begins in FY 2007. Overall funding for capital equipment is down slightly compared to FY 2006 as some resources shift to Construction, but one new Major Item of Equipment, the Reactor Neutrino Detector, begins fabrication. Capital equipment expenditures at Fermilab required to improve sections of the accelerator complex for the ongoing neutrino program continue. No AIP projects are currently planned. Funding for GPP is increased 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 post-doctoral associates developing their research and management skills. The R&D workforce developed under this program not only provides new scientific talent in areas of fundamental research, but also provides talent for a wide variety of technical, medical, and industrial areas that require the incisive thinking and problem solving abilities and 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 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 1,200 postdoctoral associates and graduate students supported by the HEP program in FY 2005 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.

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 2005, there were ~150 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 2005	FY 2006 estimate	FY 2007 estimate
# University Grants	150	135	140
# Laboratory Groups	50	47	47
# Permanent Ph.D.'s (FTEs)	1,230	1,210	1,250
# Postdoctoral Associates (FTEs)	540	540	595
# Graduate Students (FTEs)	635	585	620
# Ph.D.'s awarded	120	115	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 2007, Fermilab plans 4,560 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 operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron Collider operation. 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 2007, 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 http://www.science.doe.gov/hep/TevatronReports.shtm. The most recent review of the Tevatron operations was conducted in March 2005.

SLAC

In FY 2007, SLAC plans 5,200 hours of running to achieve a performance goal of 150 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 research program at SLAC in FY 2007. 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 thought to be responsible for the excess of matter over antimatter in the universe. The opportunity to expand the boundaries of our understanding of the origin of mass in the universe through the research conducted at this facility will continue to pay dividends in outstanding accelerator and detector performance and research quality and productivity. These efforts are more fully described in the Detailed Justification sections that follow.

HEP facilities operations funding is summarized in the table below for the Tevatron, NuMI and B-factory:

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Tevatron Complex Operations	190,305	191,500	191,500
Tevatron Complex Improvements	47,050	24,255	24,255
Total, Tevatron Complex	237,355	215,755	215,755
B-factory Operations	94,617	77,024	82,892
B-factory Improvements	14,060	16,500	10,000
Total, B-factory	108,677	93,524	92,892

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been 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 2005	FY 2006	FY 2007
Proton Accelerator-Based Physics			
Research	78,261	76,384	79,738
Facilities	313,099	298,715	296,798
Total, Proton Accelerator-Based Physics	391,360	375,099	376,536

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 evidence of new physics beyond the Standard Model.

The Proton Accelerator-Based Physics subprogram also includes precise, controlled measurements of basic neutrino properties, including neutrino oscillations, at accelerator-based neutrino facilities. These measurements will provide important clues and constraints to the theory 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 for HEP outlined in the 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 most particle physics phenomena below 1 TeV in energy, but beyond that energy range a new physical mechanism is needed to prevent Standard Model predictions from becoming inconsistent. Up until recently, it has been assumed that the Higgs boson is the solution to this "TeV scale" problem. Theories such as supersymmetry, extra hidden dimensions, and technicolor could solve the TeV scale problem in the Standard Model either in place of or in combination with, a Higgs boson. 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. A single, "standard" Higgs boson would explain the origin of mass. Supersymmetry—which has multiple Higgs bosons—not only explains the origin of mass, but could also lead to the next step in unification: combining the electroweak interaction with the strong nuclear interaction. Discovery of hidden dimensions could point the way to a unification of gravity with the other forces of nature.

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. The Tevatron collider programs will address many key questions about the Standard Model and the physics of the "TeV scale" as described above. The NuMI/MINOS program will perform decisive controlled measurements of fundamental neutrino properties, including neutrino oscillations that will provide important clues and constraints to the theory of matter and energy beyond the Standard Model. The LHC program will substantially increase the power of the U.S. high energy physics research program to explore physics beyond the Standard Model and will enable it to be a key player at the next energy frontier. There are also much smaller specialized efforts at other accelerators worldwide.

Physics at the energy frontier is the primary thrust of the Proton Accelerator-Based Physics subprogram. In FY 2007, the energy frontier remains at the Fermilab Tevatron. The CDF and D-Zero experiments will make precision measurements of known particles, like the mass of the W boson and the top quark – by far the most massive fundamental particle known. The number of top quarks accumulated and studied during the previous Tevatron collider run was less than 100. The new run will produce an order of magnitude more top quarks and allow a serious study of its mass, spin, and couplings. These precision measurements give indirect but important information about the major theories on electroweak unification and that information can guide and constrain the direct searches. They will also pursue the questions of electroweak unification with direct searches for the Higgs boson, supersymmetry, and hidden dimensions. When the LHC at CERN is operational, the energy frontier will move there and the Compact Muon Solenoid (CMS) and A Toroidal LHC Apparatus (ATLAS) experiments will take over the program begun at the Tevatron.

The Tevatron at Fermilab is the highest-energy particle accelerator in the world. It produces collisions of 1 TeV protons with 1 TeV antiprotons. Because of the high energy of the collisions and the fact that the particles interact in several different ways, the collisions can be used to study a wide variety of physics topics. All of the six different types of quarks are produced in these interactions, and the heaviest, the top and bottom quarks, are of the greatest interest. Most of the force-carrying particles are also directly produced and if the masses of predicted – but as yet unobserved – particles, such as the Higgs boson or supersymmetric particles are low enough, they will also be produced at the Tevatron. Its two large general-purpose detectors, CDF and D-Zero, mine this rich lode of physics. Precise measurements of the mass of the W boson and detailed studies of the charm quarks will also be carried out.

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

Today, neutrino physics presents one of the most promising avenues to probe for extensions of the Standard Model. There is no fundamental reason why neutrinos should not have mass or why there should be no mixing between different neutrino species. In the last decade, a number of interesting new results have been reported by several different experiments, including the Liquid Scintillation Neutrino Detector (LSND) experiment at Los Alamos, the Super-K and KamLAND experiments in Japan and the Sudbury Neutrino Observatory (SNO) experiment in Canada. These experiments provide compelling evidence that neutrinos do have mass and that they do change their identities (the different neutrino species "mix") as they travel. Unfortunately, the neutrinos used by these experiments have a wide range of energies and are produced in insufficient numbers to precisely measure their mixing parameters. One of the unique opportunities in the Proton Accelerator-Based Physics subprogram is to explore and make precision measurements of neutrinos generated at dedicated proton beam facilities in a well-controlled environment (e.g., the Neutrinos at the Main Injector beam at Fermilab).

The American Physical Society's report, *The Neutrino Matrix*, described a broad program using a variety of tools to attack the exciting opportunities 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, Electron Neutrino Appearance (EνA) Detector, will begin engineering design in FY 2007 and is planned to utilize the NuMI beam.

Research and Facilities

The Research category in the Proton Accelerator-Based Physics subprogram supports the university and laboratory based scientists performing experimental research at proton accelerator facilities in the U.S. and abroad. Experimental research activities are collaborative efforts by research groups from Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Fermilab, LBNL, and about 60 colleges and universities and include: planning, design, fabrication and installation of experiments and associated computing infrastructure; preparation for experimental operations and conduct of experiments; analysis and interpretation of data; and publication of results. These research programs are carried out at various facilities where the accelerators and detectors are located, and at the universities where many of the scientists are located. The university program also provides a small amount of funds at national laboratories (so-called "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 category 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 foreign institutions.

Highlights

Recent accomplishments include:

- The CDF and D-Zero detectors at Fermilab have collected over 8 times more data in Run II of the Tevatron collider than in all of Run I (1992-1996). The collaborations published their first papers from Run II in 2004 and have presented a large number of new results at conferences. The number of publications based on Run II data has tripled in 2005 and will continue to increase. These detectors have much greater sensitivity than before and will make numerous high-precision measurements, including the masses of the top quark and the W boson. The most recent measurements of top and W masses from CDF and D-Zero imply that the Higgs boson is most likely to have a mass around 115-120 GeV, just beyond the limits of past direct searches at CERN.

- An accelerator-based neutrino program in the U.S. was launched in 2002 when the MiniBooNE detector at Fermilab began taking data using a low-energy proton beam to confirm or refute hints of neutrino oscillations discovered at Los Alamos in the LSND experiment. The data taking will be completed and results are expected by fall of 2006.
- The NuMI beamline and the associated MINOS detectors have been completed and have begun operations. They are making precision measurements of muon neutrino properties.

The major planned efforts in FY 2007 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 2007 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 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 2007 will be data taking and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics.
- *A new detector for neutrino physics*. Engineering design begins in FY 2007 for a new experiment, the Electron Neutrino Appearance (EνA) Detector. A multi-division study from the American Physical Society has identified a series of opportunities in neutrino physics. The EνA Detector is one component of a program developed from that study. It plans to utilize 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 occurrence of these particular neutrino "flavor" changes is expected to be much rarer than the phenomenon that MINOS is studying.
- *Planning and preparation for the U.S. portion of the research program of the LHC*. A major effort in FY 2007 will continue to be the implementation 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 will continue at CERN.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**78,261**	**76,384**	**79,738**
▪ **University Research**	**45,619**	**45,526**	**47,694**

The university program consists of groups at more than 60 universities doing experiments at proton accelerator facilities. These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and post-docs. University 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 laboratory groups. University personnel are fully

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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, under fabrication at CERN; and the MINOS and MiniBooNE neutrino experiments at Fermilab and the Soudan Mine.

In FY 2007, the overall level of support is increased above the FY 2006 level-of-effort to maintain strong participation in both the Tevatron and LHC physics programs. Within the total, there will be some redirection of effort to LHC activities in FY 2007. Full participation of university physicists is needed to exploit the physics potential of the very active program at the Tevatron during FY 2007, and there will be healthy scientific competition between the completion of the Run II of Tevatron Collider program and commissioning of the LHC experiments. To the extent possible, 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 high-priority experiments such as CDF, D-Zero, and MINOS and U.S. participation in the LHC research program.

▪ **National Laboratory Research**	**31,159**	**29,696**	**30,548**

The national laboratory research program consists of groups at several laboratories participating in experiments at proton accelerator facilities. These groups participate in all phases of the experiments, with the focus of the physics program being similar to that of the university groups described above. Although they lack the specific educational mission of their colleagues at universities, they are imbedded in the laboratory structure and therefore 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 2007, the national laboratory research program is maintained at approximately the FY 2006 level of effort to maintain strong participation in both the Tevatron and LHC physics programs. Full participation of national laboratory physicists is needed to exploit the physics potential of the very active program at the Tevatron during FY 2007, and there will be healthy scientific competition between the completion of the Run II of Tevatron Collider program and commissioning of the LHC experiments. The laboratory experimental physics research groups will be focused mainly on data taking with the CDF, D-Zero, and MINOS experiments, and analysis of data taken during previous years; support for commissioning of the ATLAS and CMS detectors for the LHC; and for physicists working on preparation for U.S. participation in the LHC Research Program. HEP will monitor progress in these areas, and balance resources as needed to achieve the optimal 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, analysis of the MiniBooNE experiment, and research activities related to the neutrino initiatives, such as the EvA

	FY 2005	FY 2006	FY 2007

(dollars in thousands)

experiment. These activities by physicists at the host laboratory provide the necessary close linkages between the Research and the Facilities categories in the Proton Accelerator-Based Physics subprogram.

Research activities at LBNL will be dominated by the ATLAS research and computing program, along with analyzing data from the CDF experiment.

Activities by the BNL research group will cover data taking and analysis of the D-Zero experiment, the ATLAS research and computing program, and a small effort on the MINOS experiment and research activities related to the 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 activities related to the future neutrino initiatives.

	FY 2005	FY 2006	FY 2007
▪ **University Service Accounts**	**1,483**	**1,162**	**1,496**

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 increased in FY 2007, reflecting the overall size of the University Research program, and work at the new LHC Physics Center at Fermilab.

	FY 2005	FY 2006	FY 2007
Facilities	**313,099**	**298,715**	**296,798**
▪ **Tevatron Complex Operations**	**190,305**	**191,500**	**191,500**

Operations at Fermilab will include operation of the Tevatron accelerator complex for both collider and neutrino physics programs, including operations of two collider detectors and a neutrino experiment. In FY 2007, increased power costs for Accelerator Operations are offset as implementation of Run II accelerator upgrades is completed. For Detector Operations, improved operational efficiencies in FY 2007 offset increased costs due to infrastructure (i.e. increased power costs) and enhanced operational requirements as fully upgraded detectors come on-line.

This will be a major physics run for the D-Zero and CDF detectors with the higher intensity available from the Main Injector. The Tevatron performance has continued to improve according to plan through FY 2005 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 the running of the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This running mode will be primarily for the physics data taking of the MINOS experiment using the NuMI beamline.

	FY 2005	FY 2006	FY 2007
Tevatron Complex Operations in hours	5,040	4,320	4,560

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **Tevatron Complex Improvements**	**47,050**	**24,255**	**24,255**

The funding in this category includes GPP funds at Fermilab, funding for accelerator improvements, experimental computing expansion, and new detector fabrication. Accelerator improvements to increase the luminosity performance of the Tevatron Collider will be completed in FY 2006. In FY 2007, funding will support those improvements needed to increase the intensity and reliability of the proton source in order to enhance the neutrino physics program. In addition, the project engineering and design of the Electron Neutrino Appearance (EνA) Detector begins in FY 2007. Funding for this project is described in the Construction section of this request.

Pre-conceptual R&D is supported for a potential new small experiment in the MINOS near detector hall at Fermilab that will measure the rates of neutrino interactions with ordinary matter. This is very useful input data for MINOS and other neutrino experiments and can be done with much better precision than previous experiments with the powerful NuMI beam.

▪ **Large Hadron Collider Project**	**32,500**	**7,440**	**3,180**

The LHC has immense potential for resolving fundamental questions about the basic forces and symmetries that determine the properties of the universe. The origin of mass and the mechanism for breaking of symmetries in nature, the existence of totally new types of matter, e.g., the supersymmetric (SUSY) particles and the possibility of space having extra dimensions are but a few of the fascinating ideas that will be investigated with data from the LHC.

The goals of the physics program at the LHC include a search for the “Higgs” particle, which is thought to be responsible for the origin of mass, the exploration of the detailed properties of the top quark to determine whether this most massive fundamental object can offer insight into the nature of symmetry breaking, and the search for anticipated but not fully delineated new phenomena.

As part of the U.S. participation in the LHC program, DOE and NSF have entered into a joint agreement with CERN specifying U.S. contributions to the LHC accelerator and detectors. This agreement, approved by CERN, the DOE and the NSF in December of 1997, assures access for U.S. scientists to the premier high energy physics facility of the next decade. In addition to specifying the U.S. contributions to the LHC, as detailed below, the agreement and its incorporated protocols specify that U.S. scientific institutions have the right to fully participate in the ATLAS and CMS experiments, and that CERN will provide standard services and facilities “free of charge,” including particle beams and beam time, for the duration of the experiments.

The members of the U.S. LHC Project assumed full responsibility for the design and fabrication of specific subsystems of the accelerator complex and the two large detectors. Much of the funding for the project was therefore channeled directly to participating U.S. laboratories and university groups, and their U.S. contractors for the fabrication of subsystems and components that are to become part of the LHC accelerator or the two major detectors. Some of the project funds have also been allocated directly to CERN to pay U.S. vendors for purchases of material and components needed in the fabrication of the accelerator.

Under the agreement with CERN, U.S. DOE provides $450,000,000 to the LHC accelerator and detectors (with an additional contribution of $81,000,000 from the NSF). The DOE total is separated into detectors ($250,000,000) and accelerator ($200,000,000) with $88,500,000 for direct purchases by CERN from U.S. vendors, and $111,500,000 for fabrication of components by U.S. laboratories.

The total cost of the LHC on a basis comparable to that used for U.S. projects is estimated as about $6,000,000,000. (This estimate, prepared by CERN, does not include the costs of the permanent laboratory staff nor other standard laboratory resources made available for the design and fabrication of the LHC machine.) The total DOE contribution of $450,000,000 and the estimated cost of $6,000,000,000 for fabrication of the LHC accelerator do not include support of the European and U.S. research physicists participating in the program.

The agreement negotiated with CERN provides for U.S. involvement in the management of the project through participation on key international oversight committees (CERN Council, CERN Committee of Council, LHC Board, etc.). This offers an effective base from which to monitor the progress of the project, and helps ensure that U.S. physicists have full access to the opportunities available in the scientific program of the LHC. The Office of Science has examined the cost and schedule of the entire LHC project and has held regular reviews of the specific U.S. funded components of the LHC. The reviews have concluded that, in general, the costs were estimated properly and that the schedules were reasonable and on track, and continue to be so.

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 quite dramatically, with over 800 U.S. scientists now members of the U.S.-ATLAS detector collaboration, the U.S.-CMS detector collaboration or the U.S.-LHC accelerator consortium. Most of the effort in FY 2007 will be devoted to the U.S. LHC Research Program that will deploy the infrastructure needed for exploiting the physics opportunities presented by the new energy frontier to be opened in the first collisions at the LHC in 2007.

Previous fabrication and technical difficulties in the CERN-funded and CERN-managed portion of the LHC accelerator led to delays in the entire project. The problems now appear to be resolved, with the latest CERN schedule indicating first collisions in 2007. While the U.S. has no direct control over the LHC schedule, we maintain close contact with CERN management and the U.S. LHC project managers to ensure that schedules for U.S. deliverables conform to those of CERN. Changes in the funding profile of the three U.S. LHC projects, now matched to the updated LHC fabrication schedule developed by CERN, will enable the U.S. LHC Project to comply with the latest CERN schedule, without affecting the expected completion date or the total U.S. cost.

The detailed plans of the three U.S. LHC projects continue to be reviewed and updated in the context of any revisions by CERN. 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. Most of the equipment is already at CERN, and the remaining portion of the accelerator project is to be completed by March 30, 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 complete detectors, as well as to the purchase of computing hardware for data acquisition. Under the current schedule, this will take place in 2006 and 2007, in full agreement with the U.S. DOE deadline for the completion of the project. The increased costs arising from the delays in the initial schedule are modest and will be contained within the projects' contingency allowances. The overall result of these changes in the CERN schedule has been a stretch-out by two years in the planned U.S. contributions to the LHC detectors. The FY 2007 funding for the detectors reflects the current plans. The final cost of each detector remains unchanged.

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[b]	—	7,440	7,440	—
2007	—	3,180	3,180	—
Total	200,000[c]	250,000	450,000	81,000

[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] At the end of FY 2005 approximately 95% of the U.S. CMS and U.S. ATLAS detector projects was completed on schedule. The remaining 5% of the project scope is integrally connected to the CERN portion of the project. As such, the recent slip in the CERN project schedule will significantly impact our ability to complete the remaining 5% of this project on the present schedule. The 95% portion of this project that will be complete at the end of FY 2005 will be closed out at that time. The remaining 5% of the project will continue, consistent with DOE project management policies and practices. Based on CERN's current schedule, it is anticipated that the remaining work will be completed by the end of FY 2008, with no change in the total estimated cost of the project.

[c] 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.

LHC Accelerator and Detectors Funding Summary

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
LHC			
Accelerator Systems			
Operating Expenses	283	—	—
Capital Equipment	4,137	—	—
Total, Accelerator Systems	4,420	—	—
Procurement from Industry	17,027	—	—
ATLAS Detector			
Operating Expenses	1,626	1,642	1,034
Capital Equipment	3,863	1,598	846
Total, ATLAS Detector	5,489	3,240	1,880
CMS Detector			
Operating Expenses	2,054	1,300	50
Capital Equipment	3,510	2,900	1,250
Total, CMS Detector	5,564	4,200	1,300
Total, LHC	32,500	7,440	3,180

Changes, based on actual expenditures and progress made during FY 2005, and updated planning based on the experience during FY 2005, have been made by each of the three U.S. projects, and approved by DOE.

In FY 2006 and FY 2007, funding will be used for completing the fabrication of detector subsystems such as tracking chambers and data acquisition electronics.

All these LHC deliverables were manufactured at many different locations, including 4 DOE laboratories and 60 U.S. universities. Most are now being installed and commissioned at CERN.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
• **Accelerator Systems**	**4,420**	**—**	**—**

All fabrication activities including production of quadrupole magnets, cryogenic/electrical power feed boxes, and beam absorbers for the LHC beam interaction regions were 98% complete at the end of FY 2005, per current LHC project execution plan. Testing of superconducting wire and cable for the LHC main magnets was completed in FY 2005, as planned. No project funds are needed for the accelerator after FY 2005.

• **Procurement from Industry**	**17,027**	**—**	**—**

Final funding will be provided in FY 2005 to support reimbursement to CERN of purchases from U.S. industry that included superconducting materials, superconducting wire, superconducting cable, cable insulation, and other technical items.

	FY 2005	FY 2006	FY 2007
(dollars in thousands)			
• **ATLAS Detector**	**5,489**	**3,240**	**1,880**

In FY 2007, funding will primarily support completion of the installation and pre-commissioning of the remaining U.S.-supplied equipment at CERN, namely the transition-radiation tracker (barrel), the tile calorimeter, the silicon inner tracker, and the muon drift-tube chambers. In addition, with the imminent turn-on of the accelerator, completion of elements of the trigger and data acquisition system, and the purchase of components of associated computing hardware will be a major goal.

	FY 2005	FY 2006	FY 2007
• **CMS Detector**	**5,564**	**4,200**	**1,300**

In FY 2007, funding will primarily support completion of the installation and pre-commissioning of the remaining U.S.-supplied equipment at CERN, namely the hadron calorimeter endcap muon chambers, electronics for the electromagnetic calorimeter, and the silicon detectors, including the pixel layers. In addition, with the imminent turn-on of the accelerator, completion of elements of the trigger and data acquisition system, and the purchase of components of associated computing hardware will be a major goal.

	FY 2005	FY 2006	FY 2007
▪ **Large Hadron Collider Support**	**29,401**	**52,641**	**56,820**

With final preparations for LHC turn-on in mid 2007, the U.S. LHC Research Program, also negotiated by the DOE and NSF in the agreement with CERN, will enter a critical phase in FY 2007. Increases of 8% above FY 2006 in this area are 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. LHC effort is one of the high priority components of the HEP program, and endorsed repeatedly by HEPAP. With quality data expected before the end of FY 2008, it is imperative to focus attention on the needs anticipated during the start-up of operations in FY 2007.

Funding for pre-operations of the LHC detector subsystems built by U.S. physicists will increase somewhat in FY 2007. This effort will support the 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. CMS collaborators will perform integration tests of the major detector subsystems using final data-acquisition systems. U.S. ATLAS collaborators will commission all their detector subsystems. The effort on detector R&D, with specific focus on a possible LHC upgrade in luminosity will start to increase. Support will also be provided for technical coordination and program management and for analysis, both at the participating U.S. national laboratories and at CERN. The U.S. LHC Accelerator Research Program (LARP), supported only by the DOE, will 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 improve luminosity. This effort ramped-up significantly in FY 2006. It continues at that same level, as fabrication begins on advanced prototypes of state-of-the-art LHC interaction region magnets made of optimized niobium-tin (Nb_3Sn) superconductor material.

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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

opportunities presented by the LHC. The LHC Software and Computing program will also enter a critical year in FY 2007, when the combination of software development, facilities hardware and support, and grid computing must come together. Prior to FY 2007 the U.S. effort will be focused on serious 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 2006. The planned funding ramp-up in FY 2006 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. During this period, grid computing solutions will be integrated in the LHC computing model, providing U.S. researchers the access and computing power needed to analyze the large and complex LHC data. FY 2007 will form the final testing ground for the completed systems.

	FY 2005	FY 2006	FY 2007
▪ **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).

	FY 2005	FY 2006	FY 2007
▪ **Other Facilities**	**13,193**	**22,229**	**20,393**

Includes funding for private institutions and other government laboratories and institutions that participate in high energy physics research. This category also includes funding to respond to new opportunities and unexpected changes in facilities operations and support.

Includes $1,624,000 for General Purpose Equipment and $4,065,000 for General Plant Projects at LBNL for landlord related activities.

	FY 2005	FY 2006	FY 2007
Total, Proton Accelerator-Based Physics	**391,360**	**375,099**	**376,536**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ University Research is increased to maintain strong participation in both the Tevatron and LHC physics programs. Full participation of HEP researchers is needed to exploit the physics potential of the very active program at the Tevatron during FY 2007, in parallel with final commissioning of the LHC experiments	+2,168
▪ National Laboratory Research is increased to maintain strong participation in both the Tevatron and LHC physics programs, as above	+852

	FY 2007 vs. FY 2006 ($000)
▪ In University Service Accounts, the increase is consistent with the increased need for LHC-related work (e.g., remote commissioning activities) at Fermilab.	+334
Total, Research	**+3,354**
Facilities	
▪ In LHC Project, the decrease reflects the revised funding profile consistent with the changes to the CERN LHC completion date and its impact on the U.S. portions of the LHC detector sub-projects. The total project cost is unchanged	-4,260
▪ In LHC Support, the increase is provided in the computing systems and networks to form the final testing ground for the completed systems. The support for the detector pre-operations is also increased, as fabrication begins on initial prototypes for upgraded LHC quadrupole magnets.	+4,179
▪ In Other Facilities, resources held pending completion of peer and/or programmatic review decrease as new R&D initiatives commence.	-1,836
Total, Facilities	**-1,917**
Total Funding Change, Proton Accelerator-Based Physics	**+1,437**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Electron Accelerator-Based Physics			
Research	26,324	23,509	24,568
Facilities	108,677	93,524	92,892
Total, Electron Accelerator-Based Physics	135,001	117,033	117,460

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-accurate 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 electromagnetic and weak 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. The measurement of "CP violation" is considered by physicists to be vital to understand why the universe appears to be predominantly matter, rather than an equal quantity 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 HEP questions identified in the 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 needed to explain the fact that our universe is mostly made of matter and not antimatter.

CP violation has been observed in the decays of particles containing strange quarks (K mesons) and most recently in particles containing bottom quarks (B mesons). After the observations of CP violation in B mesons were made early in this decade at the SLAC B-factory and at the KEK B-factory, a similar accelerator in Japan at their national laboratory for high energy physics (KEK), 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 systematic study required both new measurements of CP violation in other B meson decays, and measurements of other properties of particles containing bottom or charm quarks. The measurements of these other properties have been used as inputs to the theoretical calculations of CP violation, and our limited current knowledge of those properties also limits our understanding of CP violation.

Since 1999, the BaBar experiment at the SLAC B-factory has pursued a broad program of physics studies on particles containing bottom or charm quarks as well as other measurements that support or complement the CP violation program. The Belle experiment at the KEK B-factory has carried out a very similar program. A small number of U.S. university researchers participate in the Belle experiment. There has been regular cooperation as well as competition between the BaBar and Belle experiments that has led to a better understanding of results that are more precise. The CLEO-C experiment at the Cornell Electron Storage Ring (CESR) has been concentrating on certain precision measurements of particles containing charm quarks that are difficult to do at the B-factory. These are used both for testing the theories used to interpret the CP violation measurements and as input to the physics analyses done at the B-factory.

Research and Facilities

The Research category 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 (so-called “university service accounts”) to allow university groups to perform specific tasks connected with the experimental research program.

The Facilities category 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 activities, some are partially supported by both categories of funding where appropriate.

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

Highlights

Recent accomplishments include:

- In FY 2005, the SLAC B-factory delivered 53.5 fb^{-1} (inverse femtobarns) of which the BaBar detector recorded 51.1 fb^{-1}. BaBar promptly analyzed and presented the latest results with over 170 submitted publications since 1999, of those 51 appeared during FY 2005. At a major summer conference, Lepton-Photon 2005, BaBar contributed 75 abstracts on the full spectrum of new results.
- BaBar made substantial progress in 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. Data collected to date are consistent with the current Standard Model description of CP violation, although there are possible indications of new physics in the data, as discussed below.

- Combined data from BaBar and Belle continue to show hints of possible new physics beyond the Standard Model in a class of B meson decays to particles (such as K mesons) which contain the strange quark. Current statistics are not sufficient to make a definitive measurement in any single decay mode and several related decays must be averaged to observe the effect. If the effect is real, it should be convincingly demonstrated (or ruled out) with approximately a factor of 2 increase in the total dataset for each experiment, which is expected to be accumulated by 2007.

The major planned efforts in FY 2007 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 2007 this effort will focus on data taking with the upgraded accelerator and detector. The physics issues to be addressed include expanding our understanding of the matter-antimatter asymmetry in many particle decay modes and the origin of mass in the universe.
- *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.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research..	**26,324**	**23,509**	**24,568**
▪ **University Research**	**14,865**	**15,000**	**15,539**

The university program consists of 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 post-docs. The current Electron Accelerator-Based Physics subprogram is focused on the study of charm and bottom quarks and the tau leptons that 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 that 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 will also support five groups that work at the CESR at Cornell University; and four groups that work at the KEK-B accelerator complex in Japan. The CLEO-C experiment at the CESR is concentrating on certain precision measurements of particles containing charmed quarks that are difficult to do at the B-factory. There is regular cooperation as well as competition between the SLAC and KEK experiments that has led to a better understanding of how to do the data analysis

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

leading to physics results that are more precise than they would be otherwise. University-based research efforts will be selected based on peer review.

In FY 2007, the university program is maintained at approximately the FY 2006 level-of-effort in order to support analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in the targeted physics research activities. These include research efforts related to the high priority experiments such as BaBar.

▪ **National Laboratory Research**	**11,197**	**8,275**	**8,698**

The national laboratory research program consists of groups at several laboratories participating in experiments at electron accelerator facilities with a physics program similar to the university program described above. In addition, 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 imbedded 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 software 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 2007, the national laboratory research program is increased to maintain strong participation in both the B-factory research program, and to efficiently maintain B-factory operations.

▪ **University Service Accounts**..........................	**262**	**234**	**331**

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..	**108,677**	**93,524**	**92,892**
▪ **B-factory Operations**	**94,617**	**77,024**	**82,892**

Funding for operations supports continued running of the accelerator and the operation of the BaBar detector for data collection for 5,200 hours. An additional $40,000,000 is provided for SLAC linac operations 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). Including the operations support from BES, the increase in total operations funding over FY 2006 is needed to pay for longer running time along with increased power costs.

BaBar will be the priority HEP research program at SLAC in FY 2007. It is anticipated that the collected data will be twice the total collected in FY 2006 and ensure a U.S. leadership role in the program to study the excess of matter over antimatter in the universe and allow researchers to continue to extract all the physics: resolving whether current intriguing discrepancies in physics

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

results between the SLAC B-factory and the Japanese B-factory are signs of new physics; searching for other discoveries that may be revealed with a factor of two increase in data; and maintaining a world leadership role in the field of B-physics.

	FY 2005	FY 2006	FY 2007
B-factory Operations in hours	3,380	5,200	5,200

▪ **B-factory Improvements**	**14,060**	**16,500**	**10,000**

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 provided over the past few years. Overall funding is reduced as incremental upgrades to the accelerator and detector are completed in FY 2006. Activities in this category also include support for GPP funding to renew site-wide infrastructure.

Total, Electron Accelerator-Based Physics	**135,001**	**117,033**	**117,460**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ In University Research, an increase is provided to maintain approximately the FY 2006 level-of-effort in order to carry out the BaBar research program with sufficient research personnel to analyze data and operate the BaBar detector.	+539
▪ In National Laboratory Research, an increase is provided to efficiently maintain B-factory operations and to maintain strong participation in the BaBar research program.	+423
▪ In University Service Accounts, the increase supports ongoing research of university groups working at the B-factory.	+97
Total, Research	**+1,059**
Facilities	
▪ In B-factory Operations, the increase is provided to support full operations of the B-factory in FY 2007, including increased power costs, along with higher data rates resulting from detector and accelerator upgrades completed in FY 2006.	+5,868

	FY 2007 vs. FY 2006 ($000)
▪ In B-factory Improvements, the decrease is due to the planned ramp down of accelerator and detector improvement activities	-6,500
Total, Facilities	**-632**
Total Funding Change, Electron Accelerator-Based Physics	**+427**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Non-Accelerator Physics			
University Research	15,716	16,350	17,271
National Laboratory Research	23,103	21,854	25,957
Projects	16,421	9,049	15,554
Other	350	763	489
Total, Non-Accelerator Physics	55,590	48,016	59,271

Description

The mission of the Non-Accelerator Physics subprogram is to foster fundamental research in high energy 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 aspects of the fundamental nature of particles, forces and the universe that cannot be determined solely through the use of accelerators. These activities—including the search for or measurement of dark matter and dark energy—have the capability of probing the basic structure and composition of the universe not easily or directly accessible through accelerator-based experiments and provide complementary experimental data, new ideas and techniques. The research activities explore and discover the laws of nature as they apply to the basic constituents of matter and therefore 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 HEP questions identified in the 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 pursue searches for surprising discoveries, such as dark matter, dark energy, Majorana neutrinos, proton decay, the highest energy cosmic rays, or primordial antimatter. They also study the properties of neutrinos from the sun, galactic supernovae, terrestrial nuclear reactors and cosmic rays in the earth's atmosphere. In addition, high energy gamma ray observations yield information about active galactic nuclei, gamma ray bursters, massive black holes, and particle acceleration mechanisms beyond the capabilities of 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. These experiments utilize particle physics techniques, scientific expertise, and 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 NASA, NSF, Naval Research Laboratory (NRL), and the Smithsonian Astrophysical Observatory. Strong interagency coordination and collaboration is one of the hallmarks of the projects in this subprogram. As with the rest of the HEP portfolio, most projects involve international collaboration in all phases of the experiment.

The Non-Accelerator Physics subprogram includes support for special facilities and research groups to perform these experimental measurements. While research activities (including remote site operations of Non-Accelerator Physics experiments) are covered under the Research categories, the Projects category 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 Stanford Underground Facility at Stanford University; 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 activities supported in this category include R&D and operations related to the Gamma-ray Large Area Space Telescope (GLAST), the Large Area Telescope (LAT) by SLAC, and the Alpha Magnetic Spectrometer (AMS) led by Massachusetts Institute of Technology (MIT).

Highlights

Recent accomplishments include:

- The Sloan Digital Sky Survey (SDSS), using data from its galaxy survey, the largest ever collected, measured the imprint on nearby galaxies of matter oscillations in the very early universe. These data help to explain the role of gravity in understanding how a smooth and homogenous early universe became the clumpy array of galaxies that we see today. The data collection and processing of SDSS is managed by Fermilab and is partially supported by DOE. In 2005, additional operations were approved and called SDSS-II. This data collection will continue through 2008 and will allow the study of the structure and origins of the Milky Way galaxy and the nature of dark energy.
- The Cryogenic Dark Matter Search (CDMS II) experiment completed its full complement of 5 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, 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 for discovery of dark matter particles, well into the realm where new particles are predicted by supersymmetry.

The major planned efforts in FY 2007 are:

- *Operation 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.

- *Operation of the Pierre Auger Observatory*. The Pierre Auger Observatory is the world's largest area cosmic ray detector, covering about 3,000 square kilometers in Argentina, the goal of which is to observe, understand and characterize the very highest energy cosmic rays. The full array is scheduled to begin operations in 2007, and operations have already begun with the partially completed array. This research program is being carried out by an international collaboration including scientists from U.S. universities, Fermilab, and institutions from 19 foreign countries. The U.S. part of the project has been funded jointly with the NSF and a significant contribution from the University of Chicago. Fermilab provides the project management team.
- *Operation of the Axion Dark Matter experiment (Stage I)* – The ADMX Stage I, performed at LLNL, searches for "axions," particles predicted to exist from a hypothesis explaining the smallness of CP violation (matter-antimatter asymmetry) in strong interactions, which could also account for the "dark matter" in the universe. The previous experiment set the world's best limits in the search for these particles, and work on an upgrade to the experiment was completed at the end of FY 2005. The upgraded experiment has more than twice the sensitivity of the previous version because of advanced signal amplifier electronics and larger sensitive volume. Data-taking will continue into FY 2007.
- *Operation of the Enriched Xenon Observatory 200 kilogram experiment (EXO*-200). This experiment is an outgrowth of a directed R&D program, conducted by scientists at SLAC, Stanford University, and several other U.S. universities and foreign institutes. It will be operated underground at WIPP, and will search for a process known as neutrinoless double beta decay in an active detector composed of isotopically enriched liquid xenon. This decay occurs only if neutrinos have the property that they are identical to their own anti-particles (so-called "Majorana" neutrinos). This experiment will begin operations in 2007 and is expected to set the best world limits on the existence and effective mass of Majorana neutrinos when it reports results. The EXO-200 experiment also serves as a prototype for a possible, much larger scale (~1000 kg) double beta decay experiment which could measure the neutrino mass. R&D on technical options for a large-scale experiment will be pursued.
- *Preparations for launch of the Large Area Telescope (LAT).* The LAT telescope fabrication was completed at the end of 2005 and integration on the spacecraft has commenced. The LAT is the primary instrument to be flown on NASA's GLAST mission, scheduled for launch in 2007. Its goals are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including Active Galactic Nuclei and Gamma Ray Bursters as well as search for dark matter candidates. It is complementary to the ground-based VERITAS experiment, sampling a lower energy, but somewhat overlapping, 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, NRL, U.S. universities, and institutions from Italy, France, Japan, and Sweden.
- *Participation in a Reactor Neutrino experiment*. The FY 2007 request assumes U.S. research groups will play an important role in design and fabrication of a new Major Item of Equipment, a Reactor Neutrino Detector. A multi-division study from the American Physical Society has identified

opportunities in neutrino physics, and recommended such a reactor-based experiment as part of an overall neutrino research program. This experiment will use neutrinos produced from reactors to precisely measure a crucial parameter needed to pursue the new physics opened up by the discovery of neutrino mass and mixing. The value of this parameter will help resolve ambiguities in determinations of other neutrino properties, and will help determine directions for further research in the neutrino sector.

- *R&D for future Dark Energy experiment(s)*. In order to fully determine the nature of dark energy, independent and complementary measurements are scientifically advisable. In recent years, a number of methods have been developed with different levels of theoretical and observational understanding. In FY 2007, R&D and/or conceptual design will be performed for 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; new ground telescope facilities (coordinated with the NSF); or space-based experiments, such as the SuperNova Acceleration Probe (SNAP) Experiment, a mission concept to be proposed for a space-based DOE/NASA Joint Dark Energy Mission (JDEM). In any case, proposals will be selected based on open competition and peer review. A Dark Energy Task Force has reported to both HEPAP and the Astronomy and Astrophysics Advisory Committee (AAAC) on their development of a scientific roadmap for the study of dark energy, and specific proposals will be assessed by a follow-on panel. These reports will aid in the development of a coordinated dark energy research program.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
University Research...	**15,716**	**16,350**	**17,271**

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.

These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; develop new theoretical models and provide interpretations of existing experimental data; and train graduate students and post-docs.

University physicists in this research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

In FY 2007, the university program in Non-Accelerator Physics will increase to support significant new research opportunities. Several new experiments (e.g., VERITAS, Pierre Auger, AMS, and GLAST/LAT) will have completed their fabrication phase and are moving into deployment, commissioning, operations and data analysis. To the extent possible, 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 which detects reactor-produced neutrinos in Japan; Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; CDMS-II in the Soudan Mine in Minnesota; ADMX-I at LLNL, EXO-200 at WIPP, and R&D for ground- and space-based concepts for dark energy experiments. Pre-conceptual R&D will continue

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

on a next-generation dark matter search experiment. University groups will also participate in the design, R&D and fabrication efforts for the Reactor Neutrino Detector, as described above.

R&D for a 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	**23,103**	**21,854**	**25,957**

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

In FY 2007, the laboratory research program in Non-Accelerator Physics will increase in order to support the operations of newly completed experiments (mainly GLAST/LAT). R&D activities directed at new initiatives in dark energy and neutrino physics, and ongoing R&D of next-generation detectors to directly detect dark matter will also be supported. The laboratory experimental physics research groups will be focused mainly on supporting the spacecraft integration for the GLAST/LAT telescope and analysis of previous experimental data; operations of ADMX-I; R&D for ground- and space-based concepts for dark energy experiments; analysis of data from SDSS; and, continued operation of SDSS-II. Laboratory groups will also participate in the design of the Reactor Neutrino Detector and the R&D for the double beta decay experiment as described above.

Projects	**16,421**	**9,049**	**15,554**

In FY 2007, this effort will be focused on R&D and conceptual design for the SNAP dark energy mission concept and other potential dark energy experiments; and a new Major Item of Equipment (MIE) for a Reactor Neutrino Detector. This category also includes funding for VERITAS.

Fabrication of the VERITAS telescope is scheduled to be completed at the end of FY 2006, with operations beginning at the start of FY 2007. However, in 2005, the work on VERITAS at Kitt Peak was stopped so that the National Environmental Policy Act (NEPA) process could be redone. Since the National Science Foundation holds the lease for the Kitt Peak National Observatory, they are leading the NEPA process with DOE as a cooperating agency. Due to delays incurred in this process, it is likely that the fabrication will not be completed on schedule.

The new MIE is the start of U.S. participation in fabrication of a Reactor Neutrino Detector ($3,000,000). DOE Mission Need has been approved for this experiment. This experiment would measure a crucial 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 includes the DOE contribution to the fabrication of the experiment. The technical options to deploy such an experiment are being further studied by a HEPAP Subpanel, and decisions on which option(s) to pursue will be made in 2006.

This request also supports R&D ($12,554,000) 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

	FY 2005	FY 2006	FY 2007
	(dollars in thousands)		

advisory panels (described above) as well as assessment of specific proposals. As part of this effort, the FY 2007 SNAP R&D activities will focus on the conceptual design needed for a potential future space-based mission. DOE is actively engaged with NASA on planning for JDEM.

Other	**350**	**763**	**489**

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.

Total, Non-Accelerator Physics	**55,590**	**48,016**	**59,271**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
University Research	
In University Research, the increase is provided to support significant new research opportunities with newly-operating experiments and facilities.	+921
National Laboratory Research	
In National Laboratory Research, the increase is provided to support initial operations of the GLAST/LAT telescope.	+4,103
Projects	
An increase of $3,000,000 to begin U.S. participation in fabrication of a Reactor Neutrino Detector, and an increase of $4,654,000 in the SNAP R&D effort to develop a conceptual design is offset by a decrease of $1,149,000 for the VERITAS fabrication according to the planned profile.	+6,505
Other	
The decrease reflects a slight reduction in funds held pending completion of peer and/or programmatic review.	-274
Total Funding Change, Non-Accelerator Physics	**+11,255**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Theoretical Physics			
University Research	22,975	22,500	24,043
National Laboratory Research	16,105	15,996	17,242
SciDAC	5,000	5,000	5,000
Other	5,985	4,694	5,771
Total, Theoretical Physics	50,065	48,190	52,056

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 HEP questions identified in the Overview section above.

Supporting Information

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

Research at Universities and National Laboratories

The University and National Laboratory categories of the Theoretical Physics subprogram support scientists performing research in theoretical high energy physics and related areas of theoretical physics. The research groups are based at approximately 75 colleges and universities and at 6 DOE 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 NASA and NSF. 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 (both among different disciplines of physics and between physicists and computational scientists) that have enabled 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 will re-compete 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.

Highlights

Recent accomplishments include:

- Observations of distant supernovae have indicated that the rate at which the Universe is expanding is actually accelerating, in contradiction to all expectations based on the attractive nature of the gravitational force. This discovery, which has been dubbed “dark energy,” has opened two new lines of theoretical work. One is the attempt to characterize the new phenomenon in such a way that future observations can most meaningfully confirm or deny its reality. The second is the attempt to find what new kinds of fundamental forces, or changes to the Einsteinian model of gravity, could give rise to this new aspect of Nature.

- High precision numerical simulations of the simplest strong interaction decay constants and mass differences, including the important but difficult "virtual quark" effects were recently carried out. The agreement between the calculated and experimental values was about one percent. This is an improvement by nearly an order of magnitude over previous calculations and was accomplished by the application of new highly efficient algorithms combined with the use of today's supercomputers. A major step completed during FY 2005 was the completion of a large scale prototype of a new generation of computers to enable simulations of more important processes. These simulations will require both the use of the completed prototype computer and the new computers being planned for fabrication in FY 2006 and beyond.
- Recently, powerful new techniques to calculate high energy strong interaction processes that will be measured at the LHC have been developed. These relevant analytic procedures came out of working the most esoteric branch of theoretical high energy physics, known as "string theory." In addition, sophisticated mathematical techniques are being employed to relate the spectra of new particles hopefully observed at the LHC to patterns of supersymmetry or possible extra dimensions.

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 2007:

- *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 as the origin of the masses of the elementary particles and the mechanism 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*. Quantum Chromo Dynamics (QCD) is a very successful theory that describes the strong interactions between quarks and gluons. Although the equations that define this theory are in principle exact, none of the analytical methods that are so successful elsewhere in theoretical physics are adequate to analyze it. The reason that QCD is so intractable is that it is a strongly coupled gauge field theory. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results. It has long been known that QCD can be analyzed to any desired precision by numerical methods, given enough computational power. Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made some QCD calculations feasible with quite high precision (one to two percent precision). Some of the computational tools for this effort are provided through the SciDAC program. Progress during FY 2007 will come from the continuation of the major IT investment to fabricate the necessary computer hardware in partnership with the Nuclear Physics (NP) program.
- *Neutrino Phenomenology*. The accumulating evidence that neutrinos have mass raises a host of fundamental and timely questions: whether neutrinos might be their own anti-particles; whether there might be CP violation, or even CPT violation (the combination of CP-and Time-invariance violation), in the neutrino sector; the role of neutrinos in supernova explosions; and whether neutrinos might be the origin of the matter-antimatter asymmetry in the universe. In turn these questions have strong connections to astrophysics, cosmology, and other sectors of particle physics, so that new developments have wide-ranging impacts. New theories of neutrinos are being developed, and the active worldwide program of neutrino experiments can be expected to clarify this interesting domain of elementary particles.

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

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
University Research	**22,975**	**22,500**	**24,043**

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

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 operations in FY 2007. To the extent possible, the detailed funding allocations will take into account the involvement of university-based research groups in these targeted physics research activities.

In FY 2007, the university theory program is increased above the FY 2006 level-of-effort to support university 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.

National Laboratory Research	**16,105**	**15,996**	**17,242**

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

In FY 2007, the laboratory theoretical research groups will address problems across the full range of theoretical physics research, including the analysis and interpretation of the new data expected from both the Tevatron Collider detectors, CDF and D-Zero, and preparation for the new higher energy data from the LHC. In FY 2007, the funding for the laboratory theory program will be increased above the FY 2006 level-of-effort to support laboratory research personnel participating in analysis of current and

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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.

SciDAC	**5,000**	**5,000**	**5,000**

In FY 2007, the HEP program will continue support for successful new proposals selected in the re-competition of the SciDAC program in FY 2006. Proposals will be selected based on peer review. In FY 2005 there were four principal continuing HEP-supported SciDAC efforts in the areas of: advanced accelerator beam simulations; supernova simulations; 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.

Other	**5,985**	**4,694**	**5,771**

This category 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 NP and ASCR programs is aimed toward the development of a multi-teraflops computer facility for Lattice QCD simulations. During FY 2005, a ~5 teraflops prototype computer was built using custom chip technology. The machine is called QCDOC, named for QCD On-a-Chip (QCDOC). This platform enabled U.S. researchers to stay competitive with other worldwide efforts in computational QCD research while developing a larger-scale hardware platform. During FY 2006, a joint effort with NP to develop a facility with about 13 additional teraflops capacity was started, and in FY 2007 this program will proceed as planned.

In each year of the Lattice QCD IT investment, fabrication of computers employing the most cost-effective option will be undertaken. Given current projections of price performance for this kind of high-performance computing, the HEP contribution to this effort in FY 2007 of $2,000,000 will correspond to an additional ~3 teraflops of sustained computing performance deployed, in addition to the 5 teraflops already available from the QCDOC prototype and ~3 teraflops commodity cluster that will have been fabricated by that time.

Several key R&D activities carried out from FY 2003 through FY 2006 have enabled this program. One is the successful completion and implementation of the uniform software environment on 2 types of parallel computer platforms developed for this program under SciDAC. Another is the completion and commissioning of the 5 teraflops prototype QCDOC computer at BNL in FY 2005. A third is the program of design and optimization of commercial cluster computers carried out jointly with the NP program at Fermilab and the Thomas Jefferson National Accelerator Facility (TJNAF).

In FY 2007, a program of the most important and accessible research computations on the QCDOC computer at BNL and the cluster computers at Fermilab and TJNAF will continue. This research is expected to yield high precision calculations of parameters that are needed to interpret current experiments, particularly results from the SLAC B-factory. These calculations are expected to reduce the theoretical uncertainty in interpreting experimentally measured quantities by up to a factor of 2.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

This category also includes support for the QuarkNet education project ($750,000). This project takes place in QuarkNet "centers" which are set up at universities and laboratories around the country. The eventual goal 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. In FY 2007, all of these 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.

	FY 2005	FY 2006	FY 2007
Total, Theoretical Physics	**50,065**	**48,190**	**52,056**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
University Research	
University Research is increased above the FY 2006 level-of-effort to support university researchers participating in analysis of current and previous experiments, and design and optimization of new experiments.	+1,543
National Laboratory Research	
National Laboratory Research is increased above the FY 2006 level-of-effort to support laboratory researchers participating in analysis of current and previous experiments, and design and optimization of new experiments	+1,246
Other	
Reflects an increase for the Particle Data Group ($+307,000), as well as funds held for activities under this general category pending completion of peer and/or programmatic review ($+770,000).	+1,077
Total Funding Change, Theoretical Physics	**+3,866**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Advanced Technology R&D			
Accelerator Science	27,623	27,923	33,016
Accelerator Development	47,963	58,030	88,030
Other Technology R&D	14,559	23,929	18,568
SBIR/STTR	—	18,474	19,862
Total, Advanced Technology R&D	90,145	128,356	159,476

Description

The mission of the Advanced Technology R&D subprogram is to foster fundamental research into 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, colliding beam, and detector facilities used to carry out the experimental program essential to accomplishing 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 with a particular focus on new concepts and inventions and in the reductions of these new concepts and inventions to practice; that is, developing the new technologies to the point where they can be successfully incorporated into construction projects whose performance will significantly extend the research capabilities beyond those that currently exist. Because accelerator and detector R&D underpins almost all progress in HEP research capability, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key HEP questions identified in the 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 are useful to other science programs and to industry, flow from the work carried out in this subprogram.

Supporting Information

High Energy particle physics research remains now, and for the foreseeable future, strongly dependent on the use of high energy particle beams provided by charged particle accelerators, 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 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 these 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, the applications are widely used in nuclear physics, materials science, chemistry, medicine, and industry.

In 2003, SC prepared a list of major science facilities that could be built over the next 20 years to maintain a leading U.S. scientific program of research. The list divides the needs into near term, midterm and long term. The International Linear Collider (ILC) was identified as the highest priority item for SC for a future major science facility in the midterm.

Active world-wide, inter-regional cooperation on linear collider accelerator systems, physics studies, and detector development has been underway for the past decade. In 2003, the International Linear Collider Steering Committee (ILCSC) was formed to coordinate scientific, technical, and governmental aspects of the activities leading to an international proposal to construct a linear collider. Since its inception, the ILCSC has been coordinating the activities of regional groups in the Americas, Asia, and Europe in the process of establishing a standard set of linear collider operating parameters, selection of the preferred technology to deliver the specified performance, and organizing an international collaboration. The superconducting radio frequency accelerating technology was chosen for the accelerator in September 2004. In 2005 two important steps were taken: the international organization to coordinate and provide leadership in the international R&D effort, the Global Design Effort (GDE), was established; and the GDE delivered a baseline configuration document for the ILC and established a controlled configuration change process. The baseline configuration is the basis for a reference design to be prepared by the end of 2006 and is the focus for continued progress in the internationally-coordinated R&D program.

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 ad hoc group of senior science program managers from a dozen developed nations has been formed to provide support for the GDE and begin discussions on organizing a future ILC project.

Accelerator Science

The Accelerator Science category in this subprogram focuses on the science underlying the technologies used in accelerators and storage rings. There is an emphasis on future-oriented, high-risk R&D, particularly in the development of new accelerating concepts, but essential infrastructure to support the HEP technology R&D programs is also addressed. Examples of 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 category is work on developing very high field superconducting magnet technology, studies of very high intensity proton sources for application in neutrino physics research, and muon accelerator proof-of-principle research. When concepts develop enough to be viewed as part of a larger system or as leading to a planned or possible future proposal for a construction project, they are given special attention. The ILC is the current R&D activity in this special category.

Other Technology R&D

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

Highlights

Recent accomplishments include:

- A new type of accelerator structure called the photonic band gap accelerator has been successfully tested in 2005 at an accelerating gradient of 30 MeV per meter in a university research program at MIT. The structure prototype has the unique property of being transparent to all radiofrequencies except the accelerating frequency. The photonic band gap principle was first discovered in the propagation of waves in crystals, and is now used to control the propagation of light in fiber optics for high speed communications. The gradient of 30 MeV/meter is 50% higher than the current operating gradient of 20 MeV/meter of the SLAC 50 GeV linac.
- Progress has been made on alternate methods of charged particle acceleration. In particular, current experiments at SLAC address the potential feasibility of a plasma wakefield "afterburner" that could potentially double the energy of a linear collider in only a few meters of plasma. An accelerating gradient of greater than 40 GeV per meter has been measured in a 30 centimeter long plasma channel for a net energy gain in excess of 10 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 several hundred MeV 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 2007 are:

- *Support for International Linear Collider R&D.* A TeV scale linear electron-positron collider has been identified by the international high energy particle physics community, including international advisory committees and HEPAP, as an essential international facility to extend particle physics research beyond what is feasible at the LHC. In FY 2007 pre-conceptual design will be completed and an R&D plan describing the industrialization plan, procurement plan, cost estimate, and schedule will be submitted to all participating governments. The R&D activities addressing critical performance and cost issues will be expanded and internationalized. The support for ILC R&D is expanded in FY 2007 to support a U.S. leadership role in a comprehensive, coordinated international

R&D program, and to provide the basis for U.S. industry to compete successfully for major subsystem contracts, should it be built.

- *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.
- *Neutrino Physics R&D.* In FY 2007 we are continuing a focused effort to develop the new accelerator and detector technologies that will be needed to address research opportunities in neutrino physics that have recently become accessible, and redirecting the funding to the proton accelerator and non accelerator subprograms. Neutrinos played an essential role in the evolution of the universe, and their recently-discovered tiny, non-zero masses imply new physics and unification at very high energies and have energized this area of research – discoveries await. But the very weak interactions with ordinary matter that make neutrinos such useful probes also make them very hard to detect, so new detector technologies and higher intensity accelerators are needed.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Accelerator Science	**27,623**	**27,923**	**33,016**
▪ **University Research**	**10,015**	**9,930**	**13,037**

The increase in funding in FY 2007 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 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 2007 budget will enable the restoration of the university program to a level that can provide support needed for long-term R&D, in parallel with overall program increases aimed at nearer-term R&D for future facilities. Modest new initiatives, including an expanded program in the physics of very high accelerating gradients, will be supported. Funds will also be directed at bringing the research infrastructure at some of the university-based laboratories 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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
▪ **National Laboratory Research**....................	**16,178**	**16,563**	**18,323**

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 2007, 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 2007 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.

The advanced accelerator R&D program at SLAC in FY 2007 will not include support for particle-driven plasma acceleration experiments, due to the loss of access to the necessary 30 GeV beam at the end of FY 2006, as construction of the Linac Coherent Light Source begins. However, HEP 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 category.

Other activities supported in FY 2007 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.

Funding in this category in FY 2007 is increased to enhance support for simulations and testing of new accelerator concepts, including increased operation of user facilities to meet demand.

▪ **Other**...	**1,430**	**1,430**	**1,656**

This category 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.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Accelerator Development	**47,963**	**58,030**	**88,030**
▪ **General Accelerator Development**	**24,216**	**28,030**	**28,030**

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 almost entirely done at BNL, Fermilab, LBNL and SLAC. 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.

The R&D program at Fermilab in FY 2007 will address a broad spectrum of technology needs for that facility, including development of the high-intensity neutrino super beam facility, implementation of a generic superconducting RF cavity test facility, advanced superconducting magnet R&D, advanced beam instrumentation, and simulation codes to provide improved modeling of all aspects of Tevatron operations. R&D in support of the international muon cooling collaboration with Rutherford Appleton Laboratory in the UK will continue. The LBNL R&D supported in FY 2007 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 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 2007 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.

▪ **International Linear Collider R&D**	**23,747**	**30,000**	**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. Particle physicists worldwide have strongly advised that the ILC is the tool that is needed to make the next scientific steps forward after the Large Hadron Collider (LHC) starts operations in Europe in 2007. There are strong reasons to believe that the LHC will open the door to a new domain of particles and forces. Building a coherent theory describing these particles and forces will require the precise and clean measurements that the ILC can provide. In particular: 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 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 new symmetry of nature?

In FY 2006 and FY 2007, the ILC international collaboration under the direction of the Global Design Effort will be completing a detailed review of the R&D accomplished world wide, pre-conceptual design work, and technical issues, and preparing to publish a consolidated pre-conceptual "reference" design in FY 2007. The pre-conceptual design will be used to develop the detailed R&D

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

plan, industrialization plan, procurement plan, cost estimate, and schedule. All of these will be submitted to the sponsoring governments for review. A detailed set of site requirements will also be developed and published. Starting in FY 2007, all ILC funding is 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 2007, the U.S. collaboration will continue to focus its R&D efforts on developing the high-gradient accelerating components and the steps needed to reduce their costs through industrial engagement; and designing and testing systems needed to create the high brightness beams, and the critical elements needed to bring the beams into collisions. Work will continue on improving systems reliability and large-scale simulations of the full machine. R&D on critical concepts 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. 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. sites will be performed.

Other Technology R&D	**14,559**	**23,929**	**18,568**
▪ **Advanced Detector Research**	**996**	**750**	**1,421**

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 awarded through a competitive peer review program. This program complements the detector development programs of the national laboratories.

The additional funding with respect to FY 2006 reflects the increased 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**.................................	**13,563**	**19,355**	**13,628**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories and ~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 for detector R&D related to the International Linear Collider program as well. The reduction from FY 2006 reflects the consolidation of funding for International Linear Collider detector R&D into the overall ILC program, see above.

The FY 2007 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 liquid

	FY 2005	FY 2006	FY 2007

noble gas detectors, transducer technology (e.g., advanced charged-coupled devices, silicon photomultipliers), simulation development, and fast readout electronics.

▪ **Other**	**—**	**3,824**	**3,519**

This category includes funding for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities. In FY 2006, these efforts are funded to develop new accelerator and detector concepts related to neutrino physics. A joint report of the HEP/NP neutrino physics community outlining the most promising future research directions in neutrino physics was released in Fall 2004; and a joint HEPAP/NSAC neutrino subpanel will report its recommendations early in 2006 that will help inform the decision on which research directions to pursue. These include but are not limited to: R&D for development of scintillation detectors for reactor and accelerator-based experiments; large-scale active liquid argon detectors for accelerator-based experiments; and specialized experiments to measure neutrino interaction cross-sections. In FY 2007, these activities continue, though the overall level is reduced as new experiments begin fabrication, funded in the non-accelerator subprogram (the Reactor Neutrino Detector) and under Construction (the Electron Neutrino Appearance Detector).

SBIR/STTR	**—**	**18,474**	**19,862**

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 organization of the topics and the annual solicitations for suggestions for R&D to be included in the annual solicitation are treated as an important and 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 2005, $16,105,000 was transferred to the SBIR program and $1,933,000 was transferred to the STTR program.

Total, Advanced Technology R&D	**90,145**	**128,356**	**159,476**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Accelerator Science	
▪ University Research is increased to enable the restoration of the university program to the level needed to support long-term R&D.	+3,107

	FY 2007 vs. FY 2006 ($000)
▪ National Laboratory Research is increased to enhance support for simulations and testing of new accelerator concepts, including increased operations of user facilities to meet demand.	+1,760
▪ Other Research is increased to support additional proposals pending completion of peer and/or programmatic review.	+226
Total, Accelerator Science	**+5,093**
Accelerator Development	
The increase for International Linear Collider is provided to support a U.S. leadership role in the international R&D program, and to provide the basis for U.S. industry to compete successfully for major subsystem contracts. Includes funding for ILC detector R&D and support of Global Design Effort management activities.	+30,000
Other Technology R&D	
▪ In Advanced Detector R&D, an increase is provided to support further development aimed at detectors for new experimental initiatives.	+671
▪ In Detector Development, a decrease of $4,800,000 reflects a move of ILC-related detector R&D to the ILC funding category (see above) and a redirection of $927,000 to partially support directed R&D activities	-5,727
▪ The decrease in Other reflects an overall decline in R&D for new neutrino detector initiatives as some of these efforts move into fabrication.	-305
Total, Other Technology R&D	**-5,361**
SBIR/STTR	
The increase reflects the mandated funding for the SBIR and STTR programs	+1,388
Total Funding Change, Advanced Technology R&D	**+31,120**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Construction			
07-SC-07, Electron Neutrino Appearance (EvA) Detector, PED	—	—	10,300
98-G-304, Neutrinos at the Main Injector Accelerator	745	—	—
Total, Construction	745	—	10,300

Description

This 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 2005	FY 2006	FY 2007
07-SC-07, Electron Neutrino Appearance (EvA), PED	**—**	**—**	**10,300**

The Electron Neutrino Appearance (EvA) Detector is a very large detector (approximately football-field size and five stories high), to be fabricated by Fermilab and collaborating universities, that would be sited in northern Minnesota. 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 neutrinos in an accelerator beam into electron-type neutrinos. It will also make important indirect measurements of the mass ordering 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 large "far" detector itself, the far detector enclosure, its associated electronics and data acquisition system, and a small "near" detector on the Fermilab site.

The request provides for preliminary engineering and design for both the near and far detectors, that will use the NuMI neutrino beam from Fermilab to observe for the first time the transformation of muon-type neutrinos in an accelerator beam into electron-type neutrinos.

98-G-304, Neutrinos at the Main Injector	**745**	**—**	**—**

This project, completed in the second quarter of FY 2005, provided for the construction of new facilities at Fermilab that are specially designed for the study of the properties of the neutrino and in particular to search for neutrino oscillations.

Total, Construction	**745**	**—**	**10,300**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
07-SC-07, Electron Neutrino Appearance Detector, PED	
The request supports initiation of preliminary engineering and design for a new project to observe the expected but as yet unmeasured transformation of muon neutrinos into electron neutrinos. The project will utilize the NuMI beamline recently commissioned at Fermilab and consist of two detectors, a very large one located in Minnesota and a small one on the Fermilab site.	+10,300
Total Funding Change, Construction	**+10,300**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
General Plant Projects	15,257	11,835	15,495
Accelerator Improvements Projects	5,270	4,500	—
Capital Equipment	66,851	42,165	39,927
Total, Capital Operating Expenses	87,378	58,500	55,422

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Unappro-priated Balance
07-SC-07, Electron Neutrino Appearance (EvA) Detector, PED	10,300	—	—	—	10,300	—
98-G-304, Neutrinos at the Main Injector	109,162	108,417	745	—	—	—
Total, Construction			745	—	10,300	

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 2005	FY 2006	FY 2007	Completion Date
Large Hadron Collider — Machine	111,500	91,969	87,832	4,137	—	—	FY 2006
Large Hadron Collider — ATLAS Detector	102,950[a]	55,549	49,242	3,863	1,598	846	FY 2007
Large Hadron Collider — CMS Detector	147,050[b]	71,789	64,129	3,510	2,900	1,250	FY 2007
GLAST/LAT	45,000[c]	45,000[c]	33,579	11,421	—	—	FY 2005
Run IIb D-Zero Detector	10,719[d]	10,719	8,794	1,925	—	—	FY 2006
VERITAS	7,399[e]	4,799	1,600	2,050	1,149	—	FY 2006
BaBar Instrumented Flux Return (IFR) Upgrade	4,900	4,900	3,000	1,200	700	—	FY 2006
Reactor Neutrino Detector	TBD[f]	TBD[f]	—	—	—	3,000	FY 2010
Total, Major Items of Equipment				28,106	6,347	5,096	

[a] The total U.S. contribution (TPC) for this project is $163,750,000, including $60,800,000 from NSF.
[b] The total U.S. contribution (TPC) for this project is $167,250,000, including $20,200,000 from NSF.
[c] The TEC/TPC includes DOE scope only and reflects a rebaselining approved March 2005.
[d] The total TPC for this project is $18,143,000, including $3,068,000 from NSF and $4,356,000 from foreign partners.
[e] 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.
[f] The total TPC for this project is to be determined after partnerships are identified and the project is baselined. No funding will be used for fabrication until approval and validation of the Performance Baseline and Approval of Start of Construction.

07-SC-07, Project Engineering and Design (PED), Electron Neutrino Appearance (EνA) Detector, Fermi National Accelerator Laboratory, Batavia, Illinois

1. Significant Changes

Critical Decision 0, Approval of Mission Need was granted in the 1Q FY 2006. This is a new data sheet for project engineering and design funding beginning in FY 2007. No funding will be used to initiate design until approval of Critical Decision-1, Approve Preliminary Baseline Range.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2007.......	1Q FY 2007	4Q FY 2007	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	10,300	2,000	N/A	12,300	N/A	12,300

4. Project Description, Justification, and Scope

This PED request provides Architect-Engineering (A-E) services for the preliminary and final design for the Electron Neutrino Appearance (EνA) Detector at the Fermi National Accelerator Laboratory (FNAL), including the EνA Near and Far Detectors and a building to house the Far Detector. The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction and detector fabrication costs based on the approved design, working drawings and specifications, and provide construction and fabrication schedules including procurements. The design effort will ensure that construction can physically start or long-lead items can be procured to support the EνA schedule.

Recent developments are beginning to unravel the mystery of the neutrinos. Perhaps the most significant development in the last several years is the discovery that the three known types of neutrinos mix with one another. The results of a number of experiments together provide convincing evidence for a quantum mechanical phenomenon in which neutrinos of one type turn into neutrinos of another type (oscillations). Neutrino oscillations can only occur if neutrinos have masses, since the rate of oscillation depends on the difference between the neutrino masses. This is indirect but compelling evidence that at

[a] The estimates in section 3 are for PED only. The full Total Estimated Cost (design and construction) of the EνA project at CD-0 ranges from $135,000,000 to $150,000,000. This estimate is based on preconceptual R&D and should not be construed to be a validated project baseline.

least two of the neutrinos have masses. What makes this particularly striking is that the masses of the neutrinos appear to involve a different physical mechanism than the Higgs mechanism believed to be responsible for the masses of the other known particles, the quarks and charged leptons. The only way the Higgs mechanism can be responsible for neutrino mass is if there is a new fundamental symmetry of nature. In either case the fact that neutrinos have masses has revealed new facets of nature that we do not yet understand.

The experimental study of neutrino oscillations also can offer the possibility of observing a difference in the behavior of matter and antimatter, or CP violation. In the early universe, equal quantities of matter and antimatter should have been created, but the present universe is filled with matter and not antimatter. A slight difference in the behavior of matter and antimatter has been observed in some decays of particles containing heavy quarks, but these effects are too small to explain the observed dominance of matter in the universe. There are interesting models for explaining the observed matter-antimatter asymmetry that involve new sources of CP violation in the neutrino interactions. Thus, it is important to look for CP violation in the neutrinos as well as continuing studies of CP violation with quarks.

So far, three types of neutrinos have been observed; electron neutrino, ν_e, muon neutrino, ν_μ, and the tau neutrino, ν_τ; and different detection techniques are required to observe the different types of neutrinos. Therefore, completely distinct experiments will be required to measure different types of neutrino oscillations.

For example, the "disappearance" of ν_μ has been observed by detecting fewer muon neutrinos at a distance from the source than would be expected if neutrinos do not oscillate. It is assumed that most of muon neutrinos from the original neutrino source (neutrino beam) oscillated to $\nu_{\tau,}$ since the detectors were sensitive enough to detect ν_e for such a rate of oscillation but not ν_τ. While the oscillation of ν_μ into ν_e, termed "electron ν appearance", may occur over long distances, the rate of such oscillation is small, and cannot be detected in current experiments.

Measurement of electron ν appearance together with the current disappearance measurement of ν_μ to ν_τ can provide the first logical step towards answering two important questions stated above - the unknown source of the mass of the neutrino, and the source of the matter-antimatter asymmetry (CP violation). Therefore, an experiment that is highly optimized to detect ν_e together with a high intensity neutrino source will be needed. In addition, such an experiment with a neutrino beam that travels a long enough distance will provide necessary information to determine the neutrino mass spectrum by measuring the subtle effects of the neutrino beam interacting with matter in the Earth.

Although we now are confident that neutrinos have masses, quantitatively we only know the differences in their masses; two of the neutrinos have similar masses and the other is either significantly heavier or lighter. However, we do not know which neutrino is heavier or lighter than the other two. Fully understanding neutrino masses will require that at least the mass of one neutrino be directly measured and that we determine whether the pair of similar mass neutrinos is heavier or lighter than the other neutrino (the "mass hierarchy"). It should be noted that the direct measurement of one of the masses will require a different technique such as using the neutrino-less double beta decay of certain nuclear isotopes.

A joint study on the future of neutrino physics was published in November 2004 by four divisions of the American Physical Society: Division of Nuclear Physics, Division of Particles and Fields, Division of Astrophysics, and Division of Physics of Beams. They recommended "a comprehensive U.S. program to complete our understanding of neutrino mixing, to determine the character of the neutrino mass spectrum and to search for CP violation among neutrinos." The report describes one required component of the program as, "A timely accelerator experiment with comparable $\sin^2 2\theta_{13}$ sensitivity and sensitivity to the mass hierarchy through matter effects."

The EνA project consists of a near detector on the Fermilab site, a far detector located 700-800 kilometers away in Northern Minnesota and a detector hall for that detector.

EνA Near Detector: The EνA near detector will operate on the Fermilab site at a distance of about 1 km from the NuMI target in the existing NUMI access tunnel. The purpose of the near detector is to measure backgrounds to ν_e identification that will appear in the far detector. The EνA near and far detectors are nearly identical. The only significant differences are the size, the clock speed of the electronics and the requirement that the near detector be mobile.

EνA Far Detector: The EνA far detector is optimized for detecting low-energy (~2 GeV) electron showers while rejecting background events. High signal efficiency and good background rejection require frequent sampling in materials with low atomic number.

The far detector is a 30,000 ton tracking calorimeter, 15.7 meter by 15.7 meter by 132 meter long. It is constructed from alternating vertical and horizontal cells of liquid scintillator contained in rigid plastic extrusion modules. A Wavelength Shifting fiber is inserted into each liquid scintillator cell and terminates on a pixel of a 32-pixel Avalanche Photo Diode (APD) chip. The APD is followed by front-end electronics that amplify, multiplex, digitize and zero suppress signals before passing them on to the data acquisition system.

Far Detector Hall: The EνA Project requires construction of a detector hall in Northern Minnesota to house the EνA far detector. The building will also include adequate space and infrastructure to facilitate construction and operation of the far detector. Most of the far detector hall will sit below grade. The exposed sides and top of the hall will be covered with a 3 meter overburden of dirt and rock to shield against cosmic rays.

Compliance with Project Management Order

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs presented in this Project Data Sheet are preliminary estimates for project engineering and design only. The preliminary schedule for project Critical Decisions is as follows:

- Critical Decision – 0: Approve Mission Need – 1Q FY 2006
- Critical Decision – 1: Approve Preliminary Baseline Range – 3Q FY 2006
- Critical Decision – 2: Approve Performance Baseline – 1Q FY 2007
- External Independent Review Final Report – 1Q FY 2007
- Critical Decision – 3: Approve Start of Construction – 3Q FY 2007
- Critical Decision – 4: Approve Start of Operations – 4Q FY 2011

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2007	10,300	10,300	8,300
2008	—	—	2,000
Total, Design	10,300	10,300	10,300

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design	10,300	N/A

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning	2,000	N/A

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	—	8,300	2,000	—	—	—	—	10,300
OPC (Design)	2,000	—	—	—	—	—	—	2,000
Total, Project Costs (Design)	2,000	8,300	2,000	—	—	—	—	12,300

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

A-E design services will be done by a combination of FNAL and competitively bid lump sum contracts administered by the FNAL. To the extent feasible, procurements will be accomplished by fixed-price contracts awarded on the basis of competitive bidding. Project and design management, inspection, coordination, tie-ins, testing and checkout witnessing, and acceptance will be performed by the FNAL operating contractor.

An approved Acquisition Strategy is anticipated in 3Q FY 2006 with CD-1 approval.

Nuclear Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Nuclear Physics					
Medium Energy Nuclear Physics	118,596	109,640	-1,106[a]	108,534	122,781
Heavy Ion Nuclear Physics	170,363	161,761	-1,618[a]	160,143	197,512
Low Energy Nuclear Physics	74,725	68,902	-679[a]	68,223	83,899
Nuclear Theory	30,865	28,438	-284[a]	28,154	35,348
Subtotal, Nuclear Physics	394,549	368,741	-3,687	365,054	439,540
Construction	—	2,000	-20[a]	1,980	14,520
Total, Nuclear Physics	394,549[b]	370,741	-3,707	367,034	454,060

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

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

[b] Total is reduced by $3,262,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $9,133,000, which was transferred to the SBIR program; and $1,096,000, which was transferred to the STTR program.

Strategic and Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the mission) plus seven general goals that tie to the strategic goals. The NP program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class facilities for the Nation's science enterprise.

The NP program has one program goal which contributes to General Goal 5 in the "goal cascade":
Program Goal 05.20.00.00 – Explore Nuclear Matter, from the Quarks to the 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 Program Goal 05.20.00.00 Explore Nuclear Matter, from the Quarks to the Stars

The NP subprograms (Medium Energy, Heavy Ion, Low Energy, and Nuclear Theory) contribute to Program Goal 05.20.00.00 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 program builds and supports 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, provide 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 Long-Range planning report prepared by its primary advisory panel, the Nuclear Science Advisory Committee (NSAC)–Opportunities in Nuclear Science (2002). 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 is consistent with both the DOE and SC Strategic Plans and with the SC 20-year facilities plan, Facilities for the Future of Science (2003).

The Medium Energy subprogram will contribute to Program Goal 05.20.00.00 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) 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 World-Class Scientific Research Capacity 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 Program Goal 05.20.00.00 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 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 World-Class Scientific Research Capacity 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 Program Goal 05.20.00.00 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 carried out at the Los Alamos Neutron Science Center (LANSCE) and are being developed by nuclear physicists at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. The following indicators establish specific long-term goals in World-Class Scientific Research Capacity 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 Program Goal 05.20.00.00 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 that dwarf current capabilities 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, such as the design of reactors and national and homeland security. 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.20.00.00 Explore Nuclear Matter from the Quarks to the Stars (Nuclear Physics)	394,549	367,034	454,060

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 05.20.00.00 – 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 11% 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]	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%.
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 (2.4), Hall B (7.2), and Hall C (2.1), 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 (2.8), Hall B (8.1), and Hall C (2.1), 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 (1.45), Hall B (7.7), and Hall C (1.7), 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 (2.2), Hall B (11.6), and Hall C (2.6), 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 (127,000) and recorded by the STAR (158) detectors, respectively during the polarized proton run at the Relativistic Heavy Ion Collider.
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]	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (8600) and recorded by the STAR (117) detectors, respectively, at the Relativistic Heavy Ion Collider. [Met Goal]	No Target. (The Relativistic Heavy Ion Collider is not operating in heavy ion mode during FY 2006)	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (30,000) and recorded by the STAR (100) detectors, respectively during the heavy ion run at the Relativistic Heavy Ion Collider.

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
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 (25) and Holifield Radioactive Ion Beam (5.3) 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 (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 (17.5) and Holifield Radioactive Ion Beam (1.375) 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 (1.8) 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.

The NP program 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.

The NP program is closely coordinated with the research activities of the National Science Foundation (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 the NP program collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the NP 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, 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. 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)

PART is a tool 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, and implemented by the Department to assess its programs including Nuclear Physics. 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 into the FY 2007 Budget Request and has taken the necessary steps to continue to improve performance.

In the PART review, OMB gave the NP program a score of 85% overall which corresponds to 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 2007. 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 and also available on the website, will guide review of progress toward achieving the long term Performance Measures every five years by NSAC. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report.

For the FY 2007 Budget, OMB has developed PARTWeb—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the http://ExpectMore.gov website and will improve public access to PART assessments and follow up actions. For 2006 there are three actions for Nuclear Physics:

- Responding to the recommendations of recent advisory committee reports, including implementing a budget-constrained and phased plan for the future of its research facilities.
- Engaging the National Academies, including experts outside of nuclear physics, to study the scientific capabilities of a proposed rare isotope accelerator in an international context.
- Maximizing operational efficiency of major experimental facilities in response to increasing power costs.

This budget request is one of many actions that NP is taking to respond to the recommendations of recent Nuclear Science Advisory Committee reports. NP will continue to work to maximize the utility and efficiency of major experimental facilities to ensure that the Nation's Nuclear Physics program achieves maximum results. NP has already engaged the National Academies to study the scientific opportunities of a proposed rare isotope accelerator and will encourage broad representation from the scientific community. The Academies report is expected October 2006.

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 Nuclear Science Advisory Committee 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 2005, the DOE Nuclear Physics program provided about 90% of the federal support for fundamental nuclear physics research in the Nation. The NSF provided 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 FY 2005 NSAC responded to DOE/NSF charges with four reports: (1) a review of Heavy Ion Nuclear Physics; (2) education in Nuclear Science; (3) the Neutrino Scientific Assessment Group (NuSAG) (with the High Energy Physics Program advisory committee (HEPAP)); and (4) the implementation of the 2002 Long-Range Plan. The reports can be found at http://www.sc.doe.gov/np/nsac/nsac.html.

The National Academy of Sciences (NAS) has been charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation facility in nuclear structure and astrophysics, the Rare Isotope Accelerator (RIA). The report, expected by the fall of 2006, will address the role of RIA for the future of nuclear physics, and the need for RIA within the international context of the field.

Facility directors seek advice from Program Advisory Committees (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. To supplement the S&T reviews, Facility Management and Operations Reviews are performed, where bottoms up evaluations are performed to better understand the costs and effectiveness of operations. Such reviews were conducted in FY 2002 for the Relativistic Heavy Ion Collider (RHIC) facility and Continuous Electron Beam Accelerator Facility (CEBAF), and in FY 2003-2004 for the Holifield Radioactive Ion Beam Facility (HRIBF) and the Argonne Tandem Linac Accelerator System (ATLAS) facility.

In addition, the NP program also reviews, with international experts, proposed and ongoing equipment 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.

Program Reviews

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 was the review of the Heavy Ion subprogram in 2004. Quality and productivity of university grants are peer reviewed on an approximately three-year basis and laboratory groups performing research are peer reviewed on an approximately four-year basis.

Planning and Priority Setting

The strategic plan for NP is set forth in the DOE and SC Strategic Plans. The Office of Nuclear Physics 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 major facility initiatives identified in the 2002 NSAC Long-Range Plan, the RIA and the 12 GeV CEBAF Upgrade, were incorporated into NP's strategic plan and are identified as near-term priorities in the SC future facilities plan, Facilities for the Future of Science: A Twenty-Year Outlook. Both of these initiatives have obtained Mission-Need approval by the Department.

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 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, and the Nuclear Theory and Heavy Ion subprograms, is reflected in the programmatic decisions in FY 2005 and FY 2006 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 2007 budget. These decisions have been made to maximize the scientific impact, productivity, quality and cost-effectiveness of the program within the resources available.

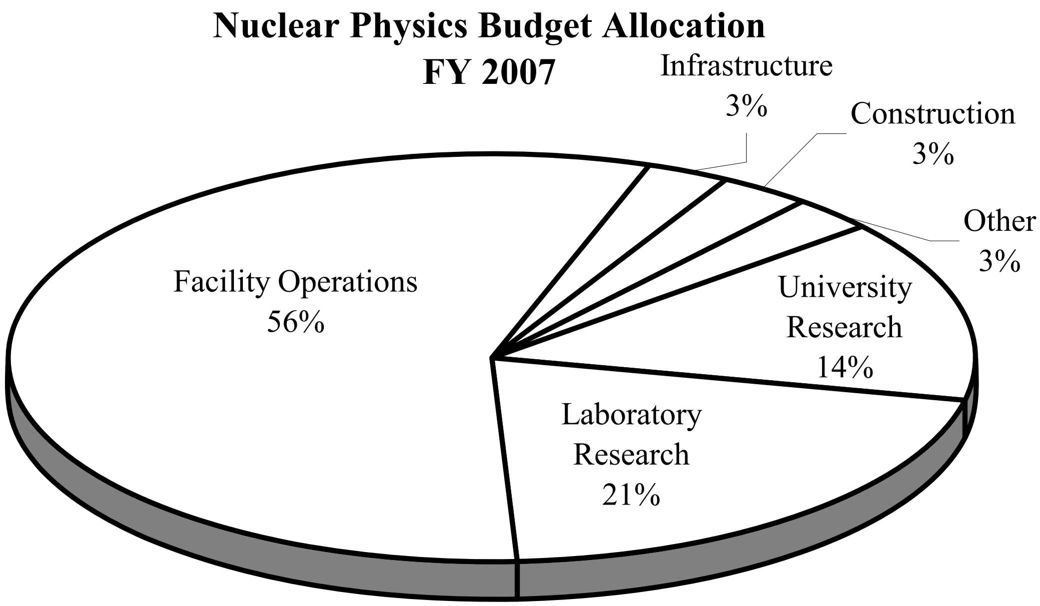
In order to better coordinate interagency activities, NP participated in the Interagency Working Group (IWG) that developed the National Science and Technology Council (NSTC) Report: A 21st Century Frontier for Discovery: The Physics of the Universe - A Strategic Plan for Federal Research at the Intersection 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 provided in FY 2007 to partially support the thrust on the Origin of the Heavy Elements at existing low-energy facilities and to support High Energy Density Physics with heavy ions at RHIC and participation at the LHC.

Committee of Visitors

A Committee of Visitors (COV), appointed by the NSAC, reviewed the management practices of the Nuclear Physics program in FY 2004. The committee examined the Office's overall operations and output, and in particular the decision process for awarding grants and for determining priorities of funding among the various activities within the Nuclear Physics program. The Committee found that the Nuclear Physics program "carries out its duties in an exemplary manner," but suggested "a number of minor operational changes which may benefit the program managers and reviewers in carrying out their tasks more efficiently." Among these was the allocation of more travel funds for program managers that has occurred in FY 2005.

How We Spend Our Budget

The FY 2007 budget request is focused on optimizing, within the resources available, the scientific productivity of the program by ensuring a proper balance of research scientists and technicians, facility operations, and investments in needed tools and capabilities. Approximately 35% of the funding is provided for research personnel to utilize the program's user facilities, complete important experiments and to fabricate experimental instrumentation. Approximately 56% of the funding is provided for operations of the program user facilities, and for support of NP's share of the in-house program at the 88-Inch Cyclotron. Approximately 6% is provided for infrastructure and for construction projects that are needed to extract the science and improve efficiencies in the outyears and approximately 3% for other activities that include Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs.



Research

About 35% of the program's funding is provided to scientists at universities and laboratories to conceive and carry out the research. The DOE Nuclear Physics 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 over 85 academic institutions located in 35 states and at 7 DOE Laboratories in 6 states. Funding is increased by ~20% compared to FY 2006. 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 2006 the DOE Nuclear Physics program supported approximately two-thirds of the Nation's university researchers and graduate students doing fundamental nuclear physics research. Among the 85 academic institutions, DOE supported 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 newly established 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/production/grants/grants.html). Proposals are reviewed by external scientific peers and competitively awarded according to the guidelines published in 10 CFR 605.

- **National Laboratory Research**: The Nuclear Physics program supports national laboratory-based research groups at Argonne, Brookhaven, 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. Laboratory researchers collaborating 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.

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.

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

Significant Program Shifts

The FY 2007 budget request increases support for operations and research by ~21% compared to FY 2006. At this funding level, overall operations of the four National User Facilities and research efforts at universities and laboratories are restored to approximately FY 2005 levels. At this level, the NP-supported user facilities allow researchers to make effective progress towards the program's scientific goals and milestones. This budget request allows for the initiation of research efforts in the CERN LHC heavy ion program and the start of support for project engineering and design (PED) activities for the 12 GeV CEBAF Upgrade project. Modest funding for generic exotic beam R&D is supported in FY 2007.

The Low Energy subprogram and the Theory subprogram, through their activities at the Nuclear Data Center, will support increased basic research efforts relevant to advanced nuclear fuel cycle issues. These subprograms will support nuclear data efforts and selected experiments that will lead to improvements in nuclear reaction cross-sections to reduce uncertainties needed to calculate the transmutation behavior for proposed advanced fuel cycles.

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.

The Nuclear Physics program funds SciDAC programs in the areas of theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (Shedding New Light on Exploding Stars: TeraScale Simulations of Neutrino-Driven Supernovae and their Nucleosynthesis), and grid technology (Particle Physics Data Grid Collaborative Pilot) that support the scientific goals of the Nuclear Physics subprograms. The principal goal of the Tera Scale Supernova simulations is to understand the mechanism responsible for the explosions of massive stars–arguably, the dominant source of most elements in the Periodic Table between oxygen and iron. The National Computational Infrastructure for Lattice Gauge Theory has as 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 complementary to a similar activity by the High Energy Physics program. The Particle Data Grid project has allowed Nuclear Physics experiments to tackle the task of replicating thousands of files at high speeds with rates in excess of 3-4 terabyte/week. In FY 2006 proposal applications will be evaluated for new or renewal grants under the SciDAC program.

Lattice Quantum ChromoDynamics Computing

Quantum ChromoDynamics is a very successful theory that describes the fundamental strong interactions between quarks and gluons. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results in high-energy and nuclear physics, including measurements at the RHIC, TJNAF, Stanford Linear Accelerator Center (SLAC) B-Factory, and the Fermi National Accelerator Laboratory (FNAL) Tevatron. Recent advances in numerical algorithms coupled with the ever-increasing performance of computers have now made a wide variety of QCD calculations feasible, though most calculations of interest still require very significant computing resources (~$10^{12\text{-}14}$ computational operations per second or 1-100 teraflops).

Together with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs, a ~5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. This platform will enable 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 computing capabilities (~ an additional 13 teraflops) began in FY 2006 to provide computing capabilities based on the most promising technology.

Scientific Facilities Utilization

In FY 2005 Nuclear Physics operated five National User Facilities including the Bates Linear Accelerator Center at the Massachusetts Institute of Technology which ceased operations in mid-FY 2005. NP's remaining four National User Facilities provide research time for scientists in universities and other Federal laboratories in FY 2006. In FY 2007, the program will support operations of these four facilities:

- 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 1,990 U.S. and international scientists. The FY 2007 Budget Request will support operations at these facilities that will provide ~19,015 hours of beam time for research, a ~66% increase over the anticipated beam hours in FY 2006.

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 2005	FY 2006	FY 2007 Request
Number of Facilities	5	4	4
Optimal Hours	25,800	22,675	22,675
Planned Operating Hours	21,660	11,435	19,015
Achieved Operating Hours	24,541	N/A	N/A
Unscheduled Downtime – Major user facilities	3,443	N/A	N/A
Number of Users[a]	2,240	2,100	1,990

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] Due to multiple facilities some users may be multiply counted.

Origin of Heavy Elements

While we have a relatively good understanding of the origin of the chemical elements in the cosmos lighter than iron, the production of the elements from iron to uranium remains a puzzle. A sequence of rapid neutron captures by nuclei known as the *r*-process (where *r* is for rapid), is clearly involved, as may be seen from the observed abundances of the various elements. Supernovae explosions, neutron-star mergers, or sources of gamma-ray bursts are possible locales for this process. Tremendous forces create the conditions that synthesize heavy elements from light elements, but our incomplete understanding of these events leaves the question open. The approach to understanding the origin and role of the heavy elements in the cosmos involves advances on several fronts including astrophysical observations of nucleosynthesis signatures in all spectral regions, studies of the abundances of elements in stars and supernovae, large-scale computer simulations for better theoretical interpretation of nuclear processes, and measurement of properties of exotic nuclei.

NP supports this area of research with studies of exotic nuclei and reactions at its existing facilities and by development of plans for exotic beam facilities.

High Energy Density Physics

When the Universe was a billionth of a second old, nuclear matter is believed to have existed in its most extreme energy density form called the quark-gluon plasma. Experiments at RHIC are searching to find and characterize this new state.

The High Energy Density Physics activities include the support of the operations of RHIC and the accompanying research program at universities and laboratories. Research and development activities, including the development of an innovative electron beam cooling system at RHIC, are expected to demonstrate the feasibility of increasing the luminosity or collision rate of the circulating beams by a factor of ten. Such an increase will allow measurements of the production rate of the J/ψ and other “charmonium” mesons that are believed to be a key indicator of possible new phenomena. With very large data samples, more precise studies will become possible of particles emanating from the hot, dense matter during its very brief existence.

The High Energy Density Physics activities include Nuclear Physics contributions to enhance the heavy ion triggering and measurement capabilities of existing LHC experiments and the accompanying research program at universities and laboratories. Experiments at the LHC are under construction that would permit measurements of the earliest highest energy density stage in the formation and development of matter at different conditions than those created at RHIC. The interplay of the different research programs at the LHC and the ongoing RHIC program will allow a detailed tomography of the hot, dense matter as it evolves from the “perfect fluid” (a fluid with zero viscosity) discovered at RHIC.

Construction and Infrastructure

In FY 2007, the increases in capital equipment (~26%) and accelerator improvement projects (~42%) are focused on projects at ATLAS and HRIBF. Funding of $7,520,000 is provided in the FY 2007 request for completion of Preliminary Engineering Design (PED) and initiation of construction for the RHIC Electron Beam Ion Source (EBIS), a joint DOE/NASA project. A Technical, Cost, Schedule, and Management review was conduced and a Critical Decision-1 (CD-1: Approve Alternative Selection and Cost Range) for the EBIS project was approved in FY 2005. The SC Office of Project Assessment conducted a Conceptual Design Review of the proposed 12 GeV CEBAF Upgrade Project to evaluate the conceptual design of the project, and assess project costs and schedules. The results of the peer review have been incorporated into the FY 2007 request, and funding of $7,000,000 is requested to initiate PED efforts in FY 2007. A CD-1 review is planned 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. Overall GPP increases by ~7% compared to FY 2006.

Workforce Development

The Nuclear Physics program supports development of the Research and Development (R&D) workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, security and industrial areas that require the finely-honed thinking and problem-solving abilities and the computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as nuclear physicists can be found in such diverse areas as nuclear medicine, medical physics, space exploration, and national security. The Outstanding Junior Investigator (OJI) program, initiated in FY 2000, through 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 900 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2005 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. In FY 2005 there were about 270 faculty researchers supported at the universities (~1.5 per grant), with an average award of ~$205,000 per faculty researcher. Almost all grants are awarded with project periods of three years.

	FY 2005	FY 2006 estimate	FY 2007 estimate
# University Grants	185	180	190
Average size (excluding CE)	$310,000	$306,000	$340,000
# Laboratory Groups	28	27	27
# Permanent Ph.D.'s	652	590	650
# Postdoctoral Associates	388	340	380
# Graduate Students	509	420	500
# Ph.D.'s awarded	80	80	80

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been 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.

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Medium Energy Nuclear Physics			
Research			
University Research	15,283	15,858	18,103
National Laboratory Research	16,009	15,567	16,983
Other Research[a]	531	5,003	5,684
Total, Research	31,823	36,428	40,770
Operations			
TJNAF Operations	77,365	69,606	80,011
Bates Facility	9,408	2,500	2,000
Total, Operations	86,773	72,106	82,011
Total, Medium Energy Nuclear Physics	118,596	108,534	122,781

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 program, 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

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[a] In FY 2005, $3,772,000 has been transferred to the SBIR program and $1,096,000 has been transferred to the STTR program. This activity also includes $3,380,000 for SBIR and $986,000 for STTR in FY 2006 and $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007.

under conditions that cannot be duplicated by man. To accomplish this task, the Medium Energy subprogram has operated the CEBAF at the Thomas Jefferson National Accelerator Facility (TJNAF), supports research at the RHIC at Brookhaven National Laboratory, and supports university researchers to carry out the experiments at these facilities. These research activities contribute to the training of the next generation of scientists and engineers that will contribute to the Department's nuclear and energy missions, as well as areas of national security.

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) measuring 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 National Synchrotron Light Source at Brookhaven, 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, has annually served a nationwide community of about 300 DOE and about 300 National Science Foundation (NSF) supported scientists and students from over 80 U.S. institutions and about 300 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 Program Advisory Committees that review and evaluate proposed experiments regarding their merit and scientific priority.

FY 2005 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:

- Approximately ten experiments world-wide, including TJNAF, have reported observing a pentaquark state while a corresponding number of experiments have not. This state, if confirmed, would be the first evidence of a particle consisting of five quarks. A new experiment at TJNAF with an order of magnitude more sensitivity finds no evidence for the pentaquark seen in previous data. This result negates earlier positive results from TJNAF and another laboratory and sets a new upper limit on the existence of the pentaquark, which challenges the significance of the remaining positive results from other laboratories.
- The TJNAF G^0 experiment, a joint DOE/NSF project with strong international participation, has completed its first phase of running to measure the contribution of strange quarks in the proton for this textbook measurement. This is the most comprehensive measurement to date that will determine the role of strange quarks in the proton's charge and magnetic distributions.

- Researchers at Argonne National Laboratory have measured the radius of the ^{6}He nucleus to be two trillionths of a millimeter with an accuracy of 0.7% by using a novel technique (Atomic Trap Trace Analysis – ATTA) of laser trapping individual atoms produced using an accelerator. The measurement will be a key benchmark because it is the first model-independent determination of the ^{6}He charge radius. The accuracy makes it possible to exclude several previous model calculations and differentiate between different three-body potentials. The group continues to develop the ATTA technology for use in fields outside of Nuclear Physics, such as geology and medicine.
- The MiniBooNE experiment, which seeks to confirm the existence of a new type of neutrino, successfully achieved its milestone of collecting neutrino events from a total proton fluence of 5×10^{20} on the production target and completed data taking in FY 2005. The experiment is expected to make public its results regarding whether a new kind of neutrino exists in FY 2006.
- The BLAST detector at the MIT/Bates facility has completed its data taking for precise measurements of the charge distribution inside the neutron and the higher order angular momentum component to the deuteron. These data will discriminate between different models of the quark structure of the neutron and different models of how the proton and neutron bind together to make the deuteron. Analysis of the data on nucleon and deuteron structure are underway.

FY 2005 Facility and Technical Accomplishments:

- TJNAF is a world-leader in superconducting radio frequency (SRF) technology. Several technical accomplishment in FY 2005 were realized including: the completion of state-of-the-art SRF cavities for the Spallation Neutron Source project; the development of particle accelerating modules that have enabled the production of the world's highest power infrared light (by a factor of more than 100) for use in the TJNAF Free Electron Laser (supported by DOD); the development of a particle accelerating module able to double the energy and resolving power of the CEBAF in preparation for the 12 GeV Upgrade; and the development and testing of particle accelerating cavities based on new superconducting material in the form of large crystals of pure Niobium that have reached close to the ultimate capability of superconducting Niobium technology in a cost-effective way, allowing the United States to take leadership in the design of an affordable potential future particle collider to understand the origins of matter and forces in nature (ILC-International Linear Collider).
- A special magnet called the "Warm Snake," designed and built in Japan by the RIKEN Research Institute, was successfully installed and commissioned in the Alternating Gradient Synchrotron (AGS) at RHIC. With this device, the average polarization of the proton beam in the RHIC ring has increased to 45%. A new complex geometry "Cold Snake" magnet using superconducting technology was successfully installed in the AGS in 2005 and is expected to further increase the absolute proton beam polarization to 60% starting in 2006.
- A new frozen deuterium target that has been in development for several years has been used in the Laser Electron Gamma Source (LEGS) experiment at Brookhaven National Laboratory to successfully acquire data for the first time. These data should resolve inconsistencies from previous measurements about the neutron's structure when it is in its first excited state. The LEGS collaboration plans to complete taking data in 2006.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**31,823**	**36,428**	**40,770**
▪ **University Research**	**15,283**	**15,858**	**18,103**

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.

• **Bates Research**	**1,985**	**—**	**—**

The BLAST detector was used to complete measurements on deuteron structure and the charge distribution of the neutron in FY 2005. With the termination of MIT/Bates operations as a National User Facility in FY 2005, funding for MIT scientists and other university researchers involved in the BLAST detector program to complete their analyses in FY 2006 and FY 2007 is shifted to Other University Research.

• **Other University Research**	**13,298**	**15,858**	**18,103**

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 will be an integral component of MIT's medium energy research effort and utilize the infrastructure remaining at the MIT/Bates facility. The unique skills of the personnel at the R&E Center enable them to effectively participate in fabrication of instrumentation and R&D 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 2007, these research efforts include 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 of the origin of spin in the proton.

▪ **National Laboratory Research**	**16,009**	**15,567**	**16,983**

Support for experimental groups at TJNAF restores CEBAF efforts to 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.

• **TJNAF Research**	**5,729**	**5,623**	**6,163**

Scientists at TJNAF, with support of the user community, assembled the large and complex experimental detectors for Halls A, B, and C. TJNAF scientists have provided necessary experimental support and operation of the detectors for safe and effective utilization by the user community. TJNAF scientists played a lead role in the laboratory's research program. In FY 2007 funding is increased relative to FY 2006 to effectively carry out the research program.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
• **Other National Laboratory Research**	**10,280**	**9,944**	**10,820**

Support for research activities at accelerator and non-accelerator facilities is increased relative to FY 2006, with resources directed towards the highest priority activities that include those described below:

- ► 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. Support is provided for these activities, as well as efforts with the Hermes experiment at Deutsches Electron-Synchrotron (DESY) that are expected to be nearing conclusion.
- ► Support will be provided to the RHIC spin physics Medium Energy Research groups at BNL and LANL. Both of these groups have important roles and responsibilities in the RHIC spin physics program.
- ► The LEGS experiment at BNL is expected to be completed in FY 2006. The FY 2007 Request provides support to complete the analysis of data.
- ► At LANL, scientists and collaborators are participating in the MiniBooNE neutrino oscillation experiment at FNAL that hopes to determine whether a new type of neutrino exists. Preliminary results are expected in FY 2006 and support will be provided in FY 2007 to complete these efforts.

	FY 2005	FY 2006	FY 2007
▪ **Other Research**	**531**	**5,003**	**5,684**

In FY 2005, $3,772,000 has been transferred to the Small Business Innovation Research (SBIR) program and $1,096,000 has been transferred to the Small Business Technology Transfer (STTR) program. This activity includes $3,380,000 for SBIR and $986,000 for STTR in FY 2006 and $3,615,000 for SBIR and $1,185,000 for STTR in FY 2007 as well as other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2005	FY 2006	FY 2007
Operations	**86,773**	**72,106**	**82,011**
▪ **TJNAF Operations**	**77,365**	**69,606**	**80,011**

Funding supports TJNAF operations and Experimental Support for a ~36-week, 3-Hall operations schedule.

	FY 2005	FY 2006	FY 2007
• **TJNAF Accelerator Operations**	**51,015**	**47,578**	**53,711**

CEBAF operations are supported for a 4,985 hour running schedule, a ~46% increase over estimated running in FY 2006. At this level of funding the accelerator provides beams simultaneously to all three experimental halls. In FY 2005, CEBAF operations exceeded estimated maximum operations; TJNAF made the decision to utilize time normally dedicated to facility maintenance and AIP installation into running time to fulfill a major commitment to a Japanese hypernucleus experiment. In FY 2007, support is directed at continuing necessary accelerator improvement projects (AIP) and General Plant Project (GPP) infrastructure

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

improvements at an increased level compared to FY 2006. Support is also provided to restore efforts in developing advances in superconducting radio-frequency technology to FY 2005 levels.

	FY 2005	FY 2006	FY 2007
CEBAF hours of operation with beam........	6,067	3,405	4,985

Funding of $2,500,000 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 Plan, and received Mission Need (CD-0) approval by the Department of Energy in March 2004. An SC Office of Project Assessment Conceptual Design Review of the project assessed the R&D plans and costing profiles for the project, and results from the review are incorporated into this budget request. Project engineering and design funding is also requested under the Construction section of this budget.

	FY 2005	FY 2006	FY 2007
• **TJNAF Experimental Support**	**26,350**	**22,028**	**26,300**

The FY 2007 request supports Experimental Support efforts at the level needed for a 36-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 2007 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 2005	FY 2006	FY 2007
▪ **Bates Facility**	**9,408**	**2,500**	**2,000**

MIT/Bates Linear Accelerator Center is provided funding related to the transfer of the Bates Center property to MIT and to indemnify DOE of any future liabilities.

	FY 2005	FY 2006	FY 2007
Bates hours of operation with beam	4,442	—	—

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 that 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 2005	FY 2006	FY 2007
Total, Medium Energy Nuclear Physics	**118,596**	**108,534**	**122,781**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ **University Research**	
Funding includes support to complete analyses of the MIT/Bates experiments and for the Research and Engineering (R&E) Center ($+2,000,000) located at MIT that capitalizes on the infrastructure and unique skills of research staff at MIT/Bates. Funding restores core university research efforts to FY 2005 levels.	+2,245
▪ **National Laboratory Research**	
Overall support for Laboratory research groups restores research efforts to FY 2005 levels. These efforts will be focused on TJNAF activities and allow more rapid completion of analyses of RHIC spin and MiniBooNE data.	+1,416
▪ **Other Research**	
Increase reflects required SBIR/STTR and other obligations	+681
Total, Research	**+4,342**
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
The FY 2007 funding request restores CEBAF accelerator operations ($+7,483,000) to near FY 2005 levels and supports a 4,985 hour running schedule. Accelerator science R&D for superconducting radio-frequency technology is increased relative to FY 2006 levels ($+585,000) and R&D for the12 GeV CEBAF Upgrade is reduced compared to FY 2006 ($-1,955,000) according to the planned profile. AIP/GPP is increased ($+20,000) compared to FY 2006.	+6,133
• **TJNAF Experimental Support**	
The FY 2007 funding request increases TJNAF experimental support by 19% relative to FY 2006 to support the facility running schedule.	+4,272
Total, TJNAF Operations	**+10,405**
▪ **Bates Facility**	
The decrease is consistent with the MIT/DOE agreement for the transfer of the Bates Center property to MIT and to indemnify DOE of any future liabilities.	-500
Total, Operations	**+9,905**
Total Funding Change, Medium Energy Nuclear Physics	**+14,247**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Heavy Ion Nuclear Physics			
Research			
University Research	12,399	11,993	14,013
National Laboratory Research	16,573	18,491	23,326
Other Research[a]	—	3,573	5,014
Total, Research	28,972	34,057	42,353
Operations			
RHIC Operations	130,624	115,451	143,327
Other Operations	10,767	10,635	11,832
Total, Operations	141,391	126,086	155,159
Total, Heavy Ion Nuclear Physics	170,363	160,143	197,512

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.

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[a] In FY 2005, $3,917,000 has been transferred to the SBIR program. This activity includes $3,573,000 for SBIR in FY 2006 and $4,918,000 for SBIR in FY 2007.

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 Bevalac (LBNL) 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 Alternating Gradient Synchrotron (BNL) 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—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 five 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; and Run 5 in FY 2005 with high luminosity copper beams and polarized protons. This facility is utilized by ~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 2005 Accomplishments

The NSAC Long-Range Plan summarized important accomplishments of the field up to 2002; since then accomplishments are summarized yearly in the budget submission. The fourth running period in FY 2004 with high luminosity gold beams produced high statistics data that afford observations of rare processes, and 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 will provide physicists with the control tests. This intermediate mass nucleus, copper, allows the RHIC experiments (BRAHMS, PHENIX, Phobos and STAR) to study system size dependence. The 2004 and 2005 data will provide greater insights into the remarkable properties of the Quark-Gluon Plasma (QGP) and the

Color Glass Condensate (CGC) matter mentioned below. Some of the highlights from the gold-gold and deuteron-gold programs are:

- The universe may have begun as a “perfect” liquid, not a gas. In April 2005, nuclear physicists working on the four experiments at RHIC presented “White Papers” documenting details of and summarizing the evidence for an extraordinary new state of matter obtained from the first 3 years of RHIC operations. These latest results show that a new state of hot, dense matter was created out of quarks and gluons, but quite different and even more remarkable than had been previously predicted. The matter created in heavy-ion collisions appears to behave like a near “perfect” liquid rather than a fiery gas of free quarks and gluons. The word “perfect” refers to the liquid’s viscosity—a friction-like property that impedes a fluid’s ability to flow. A perfect liquid has no viscosity. The RHIC results are consistent with “ideal” hydrodynamic calculations suggesting that the lowest viscosity possible in a “QGP fluid” may be achieved—a stunning discovery that could revise physicist’s conception of the earliest moments of the universe.
- Color Glass Condensate (CGC) is the name for an extreme form of nuclear matter that may have been glimpsed at RHIC in deuteron-gold collisions. In these asymmetric collisions, the deuteron is too light to create a QGP. However, according to Einstein's special theory of relativity, when a nucleus travels at near-light speed, it flattens like a pancake in its direction of motion. Also, the high energy of an accelerated nucleus may cause it to spawn a large number of gluons, the particles that hold together its quarks. These factors may transform a heavy spherical nucleus into a flattened "wall" made mostly of gluons reminiscent of a Bose-Einstein condensate. This wall, 50-1,000 times more dense than ordinary nuclei, is the CGC. Some researchers believe the QGP emerges when two CGC’s collide. While nuclear physicists are debating the evidence for a CGC, the concept itself is an accepted, if evolving, theoretical idea that might describe a universal condition of matter at relativistic energies.
- The measurements of particles emerging from RHIC collisions behave as though they had coalesced from a bath of collectively flowing, but thermally equilibrated constituent quarks. These unexpected results demonstrate that the matter produced at RHIC is dominated by sub-nucleon processes, a major milestone along the path to demonstrating the formation of the QGP.
- The matter produced at RHIC is largely opaque to quarks and gluons, as revealed most dramatically by the disappearance of high momentum jet fragments emerging in the opposite direction from a detected jet fragment in gold-gold collisions. This back-to-back correlation is present in deuteron-gold collisions. One explanation presumes that dual jets are, in fact, created near the surface of the hot, dense collision zone where one of the jets plows into an unusually opaque form of matter while the other jet escapes unimpeded in the opposite “matter-free” direction. New results indicate that the observed jet suppression depends on the orientation of the in-bound jet and thus on its path length in the opaque medium. Scientists hope to exploit this behavior using the high statistics gold data accumulated in FY 2004 and the copper data in FY 2005 to build a more detailed “tomographic” image of this hot opaque medium.
- First measurements have been made of energetic gamma rays emanating from head-on gold collisions. These “direct” photons are not suppressed and their rate is in agreement with theoretical expectations of radiation emitted from quarks and gluons.
- D mesons and J/ψ (psi) particles containing at least one heavy charm quark have been reconstructed in analysis of deuteron-gold collisions. These results will allow scientists to study the behavior and

energy loss of heavy quarks in the dense, hot matter created in gold-gold collisions using the high statistics data acquired in FY 2004.

Of great interest to researchers following the progress at RHIC is the emerging connection to other fields of science. Einstein's "Equivalence Principle," states that no experiment can distinguish the acceleration due to gravity from the inertial acceleration due to a change of velocity. In the same way, the rapid deceleration of RHIC ions as they plow into each other over a very short period of time is similar to the extreme gravitational environment in the vicinity of a black hole. This implies that RHIC collisions should emit thermal particles similar to the "Hawking radiation" emitted by a black hole. The connection between RHIC results and recent calculations using String Theory, an approach that attempts to explain the properties of the universe using 10 dimensions, is unexpected and could have a profound impact. These intriguing connections are further elaborated under the Nuclear Theory Accomplishments.

FY 2005 Facility and Technical Accomplishments:

- RHIC successfully accelerated a copper beam in FY 2005. RHIC, in its latest run with 100 GeV/nucleon copper (Cu) beams, delivered twice the planned beam luminosity of 15 inverse nanobarns (~$15nb^{-1}$) and set a new machine record. This record breaking performance has exceeded all expectations and accordingly provided significantly more data for the experiment, as well as two additional Cu runs, one at 31 GeV/nucleon and the other at 11.2 GeV/nucleon beam energy.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**28,972**	**34,057**	**42,353**
▪ **University Research**	**12,399**	**11,993**	**14,013**

Support is provided for the research of about 120 scientists and 90 graduate students at 27 universities in 21 states. Support for university research funding increases ~17% compared to FY 2006, which restores university research to levels needed to maintain effective research efforts at RHIC and the initiation 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**	**16,573**	**18,491**	**23,326**

Support is provided for scientists at five national laboratories (BNL, LBNL, LANL, LLNL, and ORNL). 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development.

	FY 2005	FY 2006	FY 2007
• **BNL RHIC Research**	**6,417**	**8,869**	**11,230**

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 2007 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 to and train young scientists. Capital equipment funds increase by $2,000,000 compared to FY 2006 to start the fabrication of the PHENIX Silicon Vertex Tracker detector (VTX) upgrade MIE (TEC ~$4,500,000), a joint project with the Japanese. 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. Funding ($2,424,000) is provided for the STAR Time of Flight (TOF) MIE, a joint project with the Chinese, at near the same level as FY 2006 to complete this project. The STAR TOF detector is a cylindrical array of Multi-gap Resistive Plate Chambers that will significantly improve particle identification capabilities of the existing STAR detector. Studies directed at developing the scientific case for a potential electron-heavy ion collider facility are supported.

	FY 2005	FY 2006	FY 2007
• **Other National Laboratory Research**	**10,156**	**9,622**	**12,096**

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 increased compared to FY 2006, funding National Laboratory Research to maintain a constant level of effort compared with FY 2005 and to selectively support high priority research. Capital Equipment funding ($+1,000,000) is provided to enable U.S. participation in the heavy-ion program at the LHC (MIE TEC ~$5,000,000). The LHC Heavy-Ion MIE received CD-0 approval and Conceptual Design and R&D are supported in FY 2006. The upgrades will provide U.S. researchers the opportunity to search for states of matter under substantially different conditions than those provided by RHIC, and obtain additional activities information regarding the nature of matter that existed during the earliest moments of the universe.

	FY 2005	FY 2006	FY 2007
▪ **Other Research**	**—**	**3,573**	**5,014**

In FY 2005, $3,917,000 has been transferred to the SBIR program. This activity includes $3,573,000 for Small Business Innovative Research (SBIR) in FY 2006 and $4,918,000 for SBIR in FY 2007.

	FY 2005	FY 2006	FY 2007
Operations	**141,391**	**126,086**	**155,159**
▪ **RHIC Operations**	**130,624**	**115,451**	**143,327**

RHIC operations are supported for a ~34-week running schedule in FY 2007 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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 shall be achieved in a timely manner.

• **RHIC Accelerator Operations**	**98,276**	**86,816**	**111,000**

Support is provided for the operation, maintenance, and improvement of the RHIC accelerator complex. This includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC. FY 2007 funding will support ~34 weeks (4,080 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 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 ($+999,000) relative to FY 2006 levels.

	FY 2005	FY 2006	FY 2007
RHIC Hours of Operation with Beam	3,862	—	4,080

• **RHIC Experimental Support**	**32,348**	**28,635**	**32,327**

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 900 scientists and students from 82 institutions and 19 countries will participate in the RHIC research program in FY 2007. With the completion of the planned scientific program of the Phobos detector in FY 2005, it is planned that three detectors will operate in FY 2007 (STAR, PHENIX and BRAHMS; described in the Office of Science Site Descriptions) that provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. FY 2007 funding will support Experimental Support efforts at the level needed for a ~34-week running schedule and to pursue important detector R&D activities. Base capital equipment funding is reduced relative to FY 2006 and redirected to the PHENIX VTX MIE project.

▪ **Other Operations**	**10,767**	**10,635**	**11,832**

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, for 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 2006 to cover requirements.

Total, Heavy Ion Nuclear Physics	**170,363**	**160,143**	**197,512**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ **University Research**	
The increase for University Research grants in FY 2007 will restore efforts to FY 2005 levels. The major focus of research will be on the RHIC program with data taking with STAR, PHENIX and BRAHMS and data analysis from all detectors, including Phobos. A modest effort will also be directed towards the initiation of an LHC heavy -ion program at CERN.	+2,020
▪ **National Laboratory Research**	
• BNL RHIC Research: Funding for capital equipment is increased by $2,000,000, to start the fabrication of the PHENIX Vertex Detector upgrade (VTX) Major Item of Equipment (MIE). Funding for the STAR TOF MIE is increased by $48,000 compared to FY 2006 to restore reductions from the FY 2006 general rescission in order to maintain the TEC and project scope. Funding for research scientific personnel is increased by 4.8% above FY 2006 ($+313,000).	+2,361
• Other National Laboratory Research: The FY 2007 request restores research efforts ($+1,353,000) to near FY 2005 levels. Additional capital equipment funds are provided for base research infrastructure ($+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.	+2,474
Total, National Laboratory Research	**+4,835**
▪ **Other Research**	
Increase reflects required SBIR obligations.	+1,441
Total, Research	**+8,296**
Operations	
▪ **RHIC Operations**	
• The FY 2007 request for Accelerator Operations supports operations of the RHIC facility for a ~34-week running schedule to meet the program's scientific goals and performance measures.	+24,184
• Experimental Support: Funding is increased by $4,583,000 for experimental scientific/technical staff and materials and supplies that effectively support the maintenance and operation of the PHENIX and STAR detectors at RHIC for a 34-week operating schedule. Offsetting the increase is a reduction of $891,000 in	

	FY 2007 vs. FY 2006 ($000)
capital equipment funds to reflect the redirection to fund the fabrication of the PHENIX Silicon Vertex Tracker detector upgrade.	+3,692
Total, RHIC Operations	**+27,876**
▪ **Other Operations**	
Increased support is provided for BNL general plant projects and general purpose equipment to increase the level of effort for FY 2007.	+1,197
Total, Operations	**+29,073**
Total Funding Change, Heavy Ion Nuclear Physics	**+37,369**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Low Energy Nuclear Physics			
Research			
University Research	18,863	17,139	19,113
National Laboratory Research	23,757	22,549	29,789
Other Research[a]	7,111	5,592	5,719
Total, Research	49,731	45,280	54,621
Operations	24,994	22,943	29,278
Total, Low Energy Nuclear Physics	74,725	68,223	83,899

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

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[a] In FY 2005, $1,444,000 has been transferred to the SBIR program. This activity includes $1,261,000 for SBIR in FY 2006 and $1,344,000 for SBIR in FY 2007.

supported, including generic exotic beam R&D relevant to next generation nuclear structure and astrophysics facilities, such as the proposed Rare Isotope Accelerator (RIA) facility. 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 astrophysics studies depends upon the availability of exotic 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 limited capabilities for these studies, a facility with next generation capabilities for short-lived radioactive beams will be needed for the U.S. to maintain a leadership role. The NSAC 2002 Long-Range Plan identified the RIA as the highest Nuclear Physics priority for a major new construction project. The Nuclear Physics program is developing a strategic plan for implementing its vision for the future. Guidance was sought from NSAC regarding opportunities and priorities for the Nuclear Physics program in the context of fiscal constraints. This guidance on the implementation of the 2002 Long-Range Plan was articulated in an NSAC report submitted in June 2005. Highest priority was recommended for the effective utilization of the program's major facilities, RHIC and CEBAF, including the planned upgrades in detector and accelerator capabilities. The report reaffirms the recommendation of the 2002 NSAC Long-Range Plan that RIA is the highest priority for new construction and that significant additional resources would be needed before proceeding with the RIA project. In FY 2007, support is provided for generic exotic beam R&D.

In FY 2007 the Low Energy Nuclear Physics subprogram supports the operation of two National User Facilities: the HRIBF at Oak Ridge National Laboratory (ORNL) and the ATLAS facility at Argonne National Laboratory (ANL). These facilities are utilized by DOE, NSF, and foreign-supported researchers. The allocation of beamtime is made with the guidance of Program Advisory Committees, consisting of scientists who review and evaluate proposed experiments regarding their merit and scientific priority. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation. In FY 2007, fabrication continues for the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE at Lawrence Berkeley National Laboratory, a segmented germanium detector array with improved position resolution and efficiency for studies with fast fragment nuclear beams. 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 made the transition in FY 2004 from a National User Facility to 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 2007.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations have been supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. Each of these university centers of excellence has a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus 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, for example the ultra-cold neutron trap at the Lujan Center at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory; the neutron experiments at LANSCE are expected to be completed in FY 2006. In FY 2007, fabrication continues for the Fundamental Neutron Physics Beamline (FNPB) MIE at the Spallation Neutron Source that will enable measurements of fundamental properties of the neutron. Other experiments do not require the use of accelerators: the Sudbury Neutrino Observatory (SNO) detector in Canada is studying the production rate and properties of solar neutrinos, while the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan is studying the properties of anti-neutrinos produced by nuclear power reactors. It is anticipated that the SNO and KamLAND detectors will be concluding their data taking phases in FY 2007.

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 100 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. In 2001, SNO reported its first physics results, which together with other experimental results, made a persuasive case for neutrino oscillations among their different types (or "flavors") and thus showed that neutrinos have mass. These results have been confirmed by new SNO measurements reported in 2002-2005, which are sensitive to the different types of neutrinos, and measurements from the KamLAND experiment with reactor produced anti-neutrinos. These results have stimulated an increasing interest in non-accelerator experiments that study neutrino properties. Studies with both SNO and KamLAND continue in order to extend and refine measurements of neutrino oscillation parameters.

FY 2005 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:

- Measurements at ATLAS establish the limits of gamma-ray satellite searches for stellar objects where the rapid proton capture process (*rp*-process) that creates elements up to at least iron has occurred. A series of measurements utilizing ATLAS beams and specialized instrumentation were able to accurately establish the probabilities for production and destruction of ^{22}Na (sodium) for the dominant reaction process. These results combined with other data, place an upper limit of 2 kilo-parsecs for the "horizon" of the INTEGRAL satellite. This puts out of observational reach objects such as the Crab Nebula that INTEGRAL was hoping to investigate.

- Results from the SNO and KamLAND provide additional information significantly constraining the neutrino oscillation parameters in the Large Mixing Angle (LMA) parameter space. SNO's second phase measurements provide the best determination yet of the neutrino mixing parameter θ_{12} (theta) describing the mixing of electron neutrinos with muon and tau neutrinos. KamLAND's results found evidence of distortion of the neutrino energy spectrum, a sensitive indicator of neutrino oscillations and a strong constraint on the neutrino mass. The KamLAND collaboration has recently reported a first measurement of neutrinos from the uranium and thorium in the earth (geo-neutrinos) that will provide information on its geophysical properties.
- Particle transfer reactions with radioactive ion beams at HRIBF have identified the energetic $i_{13/2}$ single-particle proton state in ^{135}Te (tellurium), the first time this state has been observed in a nucleus near doubly-magic ^{132}Sn (tin) (completely filled shells for both protons and neutrons). The use of low-intensity radioactive beams required the development of techniques so that the experiments could be done in inverse kinematics, with the beam of heavy particles impinging on light targets, i.e. ^{9}Be (beryllium) (^{134}Te,^{135}Te)^{8}Be transfers a single neutron to ^{135}Te. The ^{8}Be target residue decays into two alpha particles, uniquely indicating that the neutron transfer has occurred.
- The measurement of gamma-ray transition in neutron-rich Sn nuclei out to ^{134}Sn indicate that the collectivity (degree to which many nucleons act together) of doubly-magic ^{132}Sn is higher than that of the neighbors ^{130}Sn and ^{134}Sn, an unexpected result based on the systematics of nearby nuclei that have more protons than Sn. Recent advances in the intensity and purity of Sn radioactive ion beams and measurement techniques at HRIBF have enabled Coulomb excitation studies of the collectivity of core excitations of these radioactive Sn nuclei. This higher collectivity for ^{132}Sn had been qualitatively predicted with theoretical calculations using the quasi-particle random phase approximation model.
- Recent data on the structure of the thulium (Tm) nuclei at the proton dripline require model calculations can now take the departure from axial symmetry into account in the description of the observed proton decay rate and fine structure branching ratio. The structure of $^{145\text{-}147}$Tm has been mapped out and strong changes in structure as a function of mass have been uncovered utilizing Gammasphere and the Fragment Mass Analyzer at ATLAS. These structure changes in turn affect the rate of proton emission. In particular, the degree to which these deformed nuclei depart from axial symmetry was quantified and the data serve as a new, severe test of calculations of the proton decay rate and fine structure branching ratio.
- Measurements at ATLAS have established that ^{64}Ge (germanium) is not and that ^{68}Se (selenium) definitely is a "waiting point" nucleus in the astrophysical (*rp*-process). Knowledge of such "waiting point" nuclei is critical for understanding how the elements were produced in stellar burning and other astrophysical events. These are nuclei with the same number of protons and neutrons which lie on the proton drip line, at the very limits of nuclear stability, whose mass plays an important role in determining whether they will slow the process to synthesize heavier species. This then in turn affects the light curve and energy output of X-ray bursters and the distribution of the elements that are finally synthesized. The measurements are an order of magnitude more precise and free of many systematic errors that affect previous determinations.

FY 2005 Facility and Technical Accomplishments

- At LBNL, the VENUS electron cyclotron resonance (ECR) ion source, which uses superconducting technology, has been successfully commissioned with 18 and 28 giga-hertz gyrotrons providing ionized beams of metal elements up to bismuth. Preliminary data taken with bismuth beams indicate that VENUS already meets the required intensities (eight times previous ion sources) and emittance required for RIA and is relevant to ion accelerator facilities world-wide.
- In 2005 a prototype RIA gas catcher fabricated at ANL was tested with full RIA-like energy beams at the Gesellschaft fur Schwerionenforschung (GSI) facility in Germany and performed as predicted, with an extraction efficiency close to 45%. The capability to slow down fast (400 MeV/nucleon) rare fragments, stop them in a high purity gas-cell and extract them efficiently for re-acceleration is one of the major technical advances that would enable an exotic beam facility to study nuclei very far from stability.
- The fabrication of the High Power Target Laboratory (HPTL) at HRIBF was completed in FY 2005, commissioned and put into operation. The HPTL enhances the capability of the HRIBF to conduct the research necessary to develop new radioactive rare beams, increase intensity, improve isotopic purity, and explore new technologies in target/ion source combinations including laser ionization. In addition, HPTL will eventually house a second production target/ion source station that will provide increased hours of radioactive ion beam operation for experiments at HRIBF.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Research	**49,731**	**45,280**	**54,621**
▪ **University Research**	**18,863**	**17,139**	**19,113**

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 2007 funding for operation of university accelerator facilities, for capital equipment and for researchers and students is increased compared to FY 2006, providing support near the FY 2005 level. This allows for selected increases in university accelerator facility operations and enhanced research efforts in high priority areas.

- Research programs are conducted using the low energy heavy-ion beams and specialized instrumentation at the National Laboratory User facilities supported by this subprogram (the ANL-ATLAS and ORNL-HRIBF facilities). 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

	FY 2005	FY 2006	FY 2007

(dollars in thousands)

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. Equipment funds are provided for new instruments and capabilities.

- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at SNO and KamLAND (jointly with the High Energy Physics program) are supported.

	FY 2005	FY 2006	FY 2007
▪ **National Laboratory Research**	**23,757**	**22,549**	**29,789**

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

	FY 2005	FY 2006	FY 2007
• **National Laboratory User Facility Research**...........	**14,085**	**13,415**	**10,778**

Scientists at ANL and ORNL have major responsibilities for maintaining, improving and developing instrumentation for research by the user communities at the user facilities, as well as playing important roles in carrying out research that addresses the NP program's priorities. Operations of the 88-Inch Cyclotron as a National User Facility were terminated in FY 2004 and funding in FY 2005-2006 was provided to LBNL scientists to complete analyses of data taken in prior years at the 88-Inch Cyclotron. Support for LBNL scientists is shifted in FY 2007 to Other National Laboratories ($4,158,000 in FY 2006). In FY 2007 funding for ANL and ORNL research at the user facilities is increased to enhance the level of effort at these national centers for nuclear structure and astrophysics research with emphasis on high priority projects. Support is provided for the following research activities.

- ► At ORNL the research focuses on the use of radioactive beams from the HRIBF and specialized spectrometers to study the nuclear structure of nuclei far from stability. Measurements are made of reaction cross sections and nuclear properties, such as half-lives, which are crucial input to detailed astrophysics models that calculate the production of the elements in stars. Specialized equipment is employed, such as a system that integrates gamma-ray and charged-particle detectors with a recoil mass separator. The high-pressure gas target for nuclear astrophysics experiments is being utilized in an experimental program in nuclear astrophysics.
- ► At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS, coupled to ion traps, Gammasphere and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei, and to study nuclei at the extremes of excitation energy, angular momentum, deformation and isotope stability. Studies are undertaken with the Advanced Penning Trap to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model.

	FY 2005	FY 2006	FY 2007
• **Other National Laboratory Research**........................	**9,672**	**9,134**	**19,011**

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. Conceptual design and R&D activities are supported for a neutrinoless Double Beta Decay experiment that would measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle.

(dollars in thousands)

FY 2005	FY 2006	FY 2007

The increase in FY 2007 funding for Other National Laboratory Research reflects the shift in funding for the LBNL scientists involved in the 88-Inch Cyclotron in-house experimental program and support for research efforts that are also relevant to the design of next generation nuclear reactors. An increase in capital equipment funding ($+500,000) provides support to the ongoing GRETINA and FNPB MIEs, according to planned profiles, and support is also provided to initiate fabrication of a neutron Electric Dipole Moment (EDM) MIE ($+1,300,000). Resources for scientific/technical staff are increased compared to FY 2006 and are directed at the highest priority research, as described below:

- 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 GRETINA (MIE) detector, and for R&D efforts in advanced accelerator technologies and techniques.
- The Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA) MIE, for which fabrication began in FY 2004, is especially important for the study of the nuclear decay and structure of exotic 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 exotic nuclei that may exist in stars and supernovae, but live only briefly (fractions of a second). In FY 2007 funding of $3,900,000 (TEC of $17,000,000; with project completion in 2010) is provided to continue fabrication of GRETINA.
- Support is provided for groups at BNL, LBNL, and LANL that are involved in the SNO experiment, jointly built by Canada, England 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 expected to be complete in FY 2007; analysis of data and publication of results will continue.
- A LBNL effort, together with that of university groups supported by this subprogram, is supported to participate in the KamLAND and experiment in Japan that is measuring the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino "oscillations" KamLAND and has the advantage of comparing the measured fluxes to known sources. New results were reported in FY 2005 providing significant constraints on neutrino masses. Data collection is expected to be complete in FY 2007; analysis of data and publication of results will continue. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

- ► 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 Spallation Neutron Source (SNS). The FNPB will provide a world-class capability to study neutron properties, leading to a refined characterization of the weak force. Fabrication began in FY 2004 and continues in FY 2007 with funding of $1,500,000 (TEC $9,200,000).
- ► Support is provided in FY 2007 ($1,300,000) to pursue the measurement of the electric dipole moment (EDM) of the neutron, a high discovery potential experiment at the FNPB (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. The EDM MIE received CD-0 approval and Conceptual Design and R&D activities are supported in FY 2006.
- ► Funding is provided within the Low Energy subprogram to support research efforts that are also relevant to the design of next generation nuclear reactors. This research can help to provide the nuclear data and knowledge required for advanced nuclear fuel cycles. Additional funding is provided for this effort in the Theory subprogram for Nuclear Data activities. This effort is carried out in collaboration with the BES program, and a joint workshop will be conducted in FY 2006 to identify the leading scientific issues.

▪ **Other Research**	**7,111**	**5,592**	**5,719**
• **Exotic Beam R&D**	**6,736**	**3,960**	**4,000**

Funds are provided for generic R&D activities aimed at development of exotic beam capabilities.

• **SBIR and Other**	**375**	**1,632**	**1,719**

In FY 2005, $1,444,000 has been transferred to the SBIR program. This activity includes $1,261,000 for SBIR in FY 2006, and $1,344,000 for SBIR in FY 2007. Funding is also provided for other established obligations ($371,000) including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

Operations	**24,994**	**22,943**	**29,278**
▪ **User Facility Operations**	**24,844**	**22,793**	**25,992**

Support is provided for the operation of two National User Facilities, the ATLAS at ANL and the HRIBF at ORNL, for studies of nuclear reactions, structure and fundamental interactions. In FY 2005 and 2006, funding was provided in this budget category also for the operations of the 88-Inch Cyclotron at LBNL. Operations at the 88-Inch Cyclotron as a Nuclear Physics National User Facility were terminated in FY 2004 and since that time it has provided beams for applied researcher users and a limited in-house program. In FY 2007 NP support of operations of the 88-Inch Cyclotron ($3,000,000 in FY 2006) for an in-house program is moved to Other Operations to reflect its current status.

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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

Array for nuclear astrophysics studies. In FY 2007, funding restores accelerator operations to near FY 2005 levels, 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.

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, and fundamental and decay properties of nuclei. In FY 2007, funding restores accelerator operations to near FY 2005 levels. Accelerator improvement project funding supports upgrading the accelerator to increase the radioactive beam capabilities of ATLAS.

In FY 2006 these low energy facilities will carry out about 80 experiments involving about 300 U.S. and foreign researchers. Planned hours of operation in FY 2006 and FY 2007 with beam are indicated below; the FY 2005 hours are actual beam hours provided:

	FY 2005	FY 2006	FY 2007
ATLAS Hours of Operation with Beam	5,301	4,380	5,600
HRIBF Hours of Operation with Beam	4,869	3,650	4,350
Total Beam Hours for Low Energy Facilities	10,170	8,030	9,950

▪ **Other Operations**	**150**	**150**	**3,286**

Operations at the 88-Inch Cyclotron made a transition in FY 2004 from a National User Facility to a facility providing beams for applied researcher users and a limited in-house program. This was done to provide resources to optimize the utilization and science productivity of the remaining user facilities, consistent with the recommendations of the NSAC Low Energy Program Review in 2001. In late FY 2003 the National Reconnaissance Office (NRO) and the Air Force (USAF) determined that operation of the 88-Inch Cyclotron was essential for production of heavy-ion beams that could be used to simulate cosmic ray damage to electronic components that would be used in space, and joint operations was undertaken by the three agencies. A continued need for the beam capabilities of the 88-Inch Cyclotron has been identified by the NRO and the USAF, and a Memorandum of Agreement (MOA) for the continuation of the joint operations for FY 2006-2011 has been signed. In accord with the MOA, in FY 2007 the NRO and USAF will utilize the 88-Inch Cyclotron for approximately 2,000 hours for their testing program, and Nuclear Physics will utilize it for an approximately 3,000 hour in-house nuclear physics research program. The NRO and USAF will provide a total of $2,200,000 and NP will provide $3,136,000 for joint operations of the facility. This funding was included under User Facility Operations through FY 2006.

Funding is also provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.

Total, Low Energy Nuclear Physics.......................................	**74,725**	**68,223**	**83,899**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Research	
▪ **University Research**	
FY 2007 funding increases by ~11% compared to FY 2006, providing for a return to the FY 2005 level of effort and allowing for increased operations of university accelerators, more effective extraction of science from the user facilities operated by the program and enhanced efforts in high-priority non-accelerator initiatives.	+1,974
▪ **National Laboratory Research**	
• **National Laboratory User Facility Research:** FY 2007 funding increases ($+1,521,000) compared to FY 2006 for high priority research efforts and activities at the ATLAS and HRIBF, which are needed for effective and productive exploitation of the beams at these user facilities. Funding for the LBNL 88-Inch Cyclotron activities is shifted to Other National Laboratory Research ($4,158,000 in FY 2006).	-2,637
• **Other National Laboratory Research:** FY 2007 funding provides an increase ($+1,967,000) for scientific/technical staff support compared to FY 2006, to restore research efforts for low energy accelerator activities to FY 2005 levels. Funding is also increased for capital equipment ($+2,322,000), including the ongoing fabrication of the GRETINA and FNPB MIEs, and the funding for initiation of the new EDM neutron MIE. The increase includes support for the LBNL scientists involved in the 88-Inch Cyclotron in-house experimental program ($4,158,000 in FY 2006) previously funded in National Laboratory User Facility Research. Finally, funding ($+1,430,000) is provided for research activities relevant to the design of next generation nuclear reactors.	+9,877
Total, National Laboratory Research	**+7,240**
▪ **Other Research**	
The increase reflects required SBIR/STTR and other obligations.	+127
Total, Research	**+9,341**

Operations

▪ **User Facilities Operations:** Support for 88-Inch Cyclotron operations ($3,000,000 in FY 2006) is transferred to Other Operations. The change from FY 2006 for HRIBF & ATLAS Operations, including AIP and CE, is $+6,199,000 as follows: increases for operations for HRIBF ($+1,508,000) and ATLAS ($+2,560,000) restores running time to planned FY 2005 levels (9,950 hours); CE investments ($+1,416,000) are aimed at instrumentation necessary to carry out the experimental program; investments in AIP at HRIBF ($+117,000) support continued fabrication

	FY 2007 vs. FY 2006 ($000)
of a second source and transport beamline for radioactive ions and at ATLAS ($+598,000) to develop an ion source for unique capabilities for radioactive beams.....	+3,199
▪ **Other Operations** increases due to the transfer of funding for the 88-Inch Cyclotron in FY 2007 from User Facility Operations.	+3,136
Total, Operations	**+6,335**
Total Funding Change, Low Energy Nuclear Physics..	**+15,676**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Nuclear Theory			
Theory Research			
University Research	13,054	11,018	14,229
National Laboratory Research	10,389	10,570	11,718
Scientific Discovery through Advanced Computing (SciDAC)	1,985	1,485	2,500
Total, Theory Research	25,428	23,073	28,447
Nuclear Data Activities	5,437	5,081	6,901
Total, Nuclear Theory	30,865	28,154	35,348

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 new Relativistic Heavy Ion Collider (RHIC) facility. Lattice QCD theory predicts that the physical vacuum "melts" at extremely high temperatures and the underlying symmetries of QCD 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 sponsors the national Institute for Nuclear Theory (INT), based at the University of Washington, in Seattle, Washington, where visiting scientists focus on key frontier areas in nuclear physics, including those crucial to the success of existing and future experimental facilities and the education of postdoctoral researchers and graduate students. The subprogram is responding to the need for large dedicated computational resources for Lattice Quantum ChromoDynamical (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, a ~5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. This platform will enable 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 (~an additional 13 teraflops) will begin in FY 2006 to provide computing capabilities based on the most promising technology.

The program is enhanced through interactions with complementary programs overseas, with efforts supported by the National Science Foundation, with programs supported by the High Energy Physics program and with the Japanese supported theoretical efforts related to RHIC at the RIKEN Center at Brookhaven National Laboratory. Many foreign theorists participate on advisory groups as peer reviewers. There is large participation in the INT by researchers from Europe and Japan and by researchers in overlapping fields such as astrophysics, atomic and molecular physics, condensed matter physics and particle physics.

Included in the theory subprogram are the activities that are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

Progress in Nuclear Theory is included as a component in reviews of the three major experimental subprograms within the Nuclear Physics program.

FY 2005 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:

- *Indicators of quark-gluon plasma formation:* It has recently been pointed out by NP supported theorists at BNL that collisions at Brookhaven's RHIC produce the analog of a black hole. This is due to a mathematical similarity between the physics of RHIC collisions and the physics that is used to describe a black hole in a multi-dimensional world. This stems from Einstein's Equivalence Principle: the rapid deceleration of RHIC ions as they smash into each other is similar to the extreme gravitational environment in the vicinity of a black hole. This means that RHIC collisions should emit thermal particles similar to the Hawking radiation emitted by a black hole. The "black hole thermalization" scenario naturally explains the rapid thermalization that occurs, and provides a set of further predictions that can be tested at RHIC.
- *New regions of nuclear structure:* Superheavy nuclei represent the limit of nuclear mass and charge; they inhabit the remote corner of the nuclear landscape, whose extent is unknown. The existence of such heavy nuclei hangs on a subtle balance between the attractive nuclear force and the disruptive Coulomb repulsion between protons that favors fission. Theorists supported by NP have modeled the interplay between these forces in an approach that accounts for shape deformation through the Jahn–Teller effect, a general description of spontaneous symmetry breaking. These theorists predict that the long-lived superheavy elements can exist in a variety of shapes, including spherical, axial and triaxial configurations. In some cases, they anticipate the existence of metastable states and shape isomers that can affect decay properties and hence nuclear half-lives.
- *Studies of Fermi gases: superfluids and nearly perfect fluids:* Determining the properties of Fermi gases is an intriguing topic for many-body physics, with applications to phenomena such as the outer crust of neutron stars, pairing in neutron rich nuclei, ultracold atomic gases trapped in controllable laboratory experiments, and to the predicted color superconducting phase in dense quark matter. A crossover from the Bardeen-Cooper-Schrieffer (BCS) superfluid state to a Bose-Einstein condensation (BEC) state is expected to occur if the force between the fermions (nucleons, quarks, alkali atoms) is attractive. When interactions are strong enough so that a bound state is possible, the fermions first form bound states (bosons). As the attraction increases they start to condense into the bosonic zero-mode at some critical temperature T_c. If the bound state occurs at threshold, universal behavior is expected and the crossover temperature could be experimentally attainable. Theoretical study of this limit is difficult because it occurs at strong coupling. Lattice field theory provides a first principles approach to the study of nonrelativistic strongly interacting systems such as this through Monte Carlo simulation. Preliminary results in the universal region have been obtained for the critical temperature T_c from such a study.

- *Experimental indication of an almost perfect fluid produced at RHIC:* The current understanding of almost perfect fluids arises from a mathematical relationship known as the Maldacena duality which relates gauge theories (such as QCD) to ten-dimensional gravity within string theory. Recently NP supported theorists combined the Maldacena duality with hydrodynamics. That marriage enabled them to calculate a plasma's coefficient of shear viscosity, a parameter that describes how forces are transmitted transversely in fluids. This year they sharpened an earlier conjecture that there exists a lower bound to the ratio of shear viscosity to entropy density for a wide class of fluids. The result can be expressed in terms of fundamental constants and is many orders of magnitude lower than this ratio in water, for example. Results from RHIC and observations of strongly interacting lithium-6 atoms suggest that the extremely low viscosities calculated from this analogy with string theory may be more than just a theoretical curiosity. The post-collision medium seems to behave more like a strongly interacting fluid than a gas; detailed results of RHIC collisions are in excellent accord with the hydrodynamic limit of zero shear viscosity.
- *Studies of hadronic structure on the lattice:* The simulation of light dynamical quarks constitutes one of the major challenges in contemporary lattice gauge theory research. The computational obstacle has in the past been addressed by investigating new algorithms. Recently, a new approach has been attempted employing a so-called "hybrid" scheme where different types of sea and valence quarks are used. This new approach has been applied to the proton form factor and the nucleon axial coupling, g_A. Calculations in a fixed volume underestimate g_A when the pion becomes too light to fit in the chosen volume, but a sequence of calculations in three volumes using this new method produces a locus of points that smoothly extrapolate to the experimental result. Encouraged by the successes reported here, researchers are continuing the calculation of hadronic observables using improved staggered sea quarks and domain-wall valence quarks.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Theory Research	**25,428**	**23,073**	**28,447**
▪ **University Research**	**13,054**	**11,018**	**14,229**

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 2007 funding is increased compared with FY 2006 for theoretical efforts needed for interpretation of experimental results obtained at the program facilities. The program will be optimized to focus efforts on the high priority activities which are aligned with SC Strategic Plan milestones. Following a recommendation of the NSAC Theory Review subcommittee 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. These programs result in new ideas and approaches, the formation of collaborations to attack specific problems, and the opportunity for interactions of researchers from different fields of study. For example, recent programs have resulted in a new research effort that fuses modern shell model

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

technology with effective field theory to potentially provide a tractable, rigorous solution for low energy properties of nuclei. Another program on the "Quark and Gluon Structure of Nucleons and Nuclei" contributed significantly to the development of the concept of generalized parton distributions. The key papers on the subject were either written at the workshop or based on discussions that took place at the INT.

▪ **National Laboratory Research**	**10,389**	**10,570**	**11,718**

Research programs are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). In FY 2007 funding for scientific/technical staff is increased compared with FY 2006 in order to address theoretical issues important for advancing the national nuclear physics program. The range of topics in these programs is broad, and each of the active areas of experimental nuclear physics is supported by at least some of these nuclear theory activities. 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.

▪ **Scientific Discovery through Advanced Computing (SciDAC)**	**1,985**	**1,485**	**2,500**

Scientific Discovery through Advanced Computing (SciDAC) is an SC program to address major scientific challenges that require advances in scientific computing using terascale resources. In FY 2001 several major multi-institutional grants in high-priority topical areas were awarded through this program for the first time by the then combined High Energy and Nuclear Physics (HENP) programs. Currently theoretical nuclear physics supports the National Computation Infrastructure for Lattice Gauge Theory (the gauge theory relevant to contemporary nuclear physics is QCD) and an award titled Shedding New Light on Exploding Stars: Terascale Simulation of Neutrino-Driven Supernovae and their Nucleosynthesis-TSI. The former award led to one of the achievements noted earlier, and the TSI endeavor appears to be in line with meeting an SC 2006 milestone to "develop three-dimensional computer simulation for the behavior of supernovae, including core collapse and explosion, which incorporate the relevant nuclear reaction dynamics." All current SciDAC projects were completed in FY 2005 and a new competition is being held in FY 2006. In FY 2007 funding for SciDAC activities is increased compared to FY 2006, allowing for enhanced efforts in the most promising areas for progress in nuclear physics with terascale computing capabilities.

Nuclear Data Activities	**5,437**	**5,081**	**6,901**

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 is increased ($+820,000) relative to FY 2006, allowing for retentions and recruitment of skilled personnel that are needed to maintain the Nation's nuclear data base. This is a critical issue, with over 50% of the compilers and evaluators over 60 years old, retired and working part-time. 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

who perform data assessment as well as developing modern network dissemination capabilities. The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

Funding is also provided within the Nuclear Data activities in the Theory subprogram to support ongoing research efforts that are also relevant to the design of next generation nuclear reactors, including covariant matrix studies, cross section evaluations and other activities. Additional funding is provided for this effort in the Low Energy subprogram. This effort is carried out in collaboration with the BES program, and a joint workshop will be conducted in FY 2006 to identify the leading scientific issues.

	FY 2005	FY 2006	FY 2007
Total, Nuclear Theory	**30,865**	**28,154**	**35,348**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Theory Research	
▪ **University Research**	
FY 2007 funding is increased compared to FY 2006, funding personnel at levels needed to support the national Nuclear Physics program. Resources will be focused on the theoretical understanding of the research that was identified in SC Strategic Plan Milestones and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory.	+3,211
▪ **National Laboratory Research**	
FY 2007 funding is increased compared to FY 2006 to provide needed theoretical efforts for the national nuclear physics program. Research will be directed toward achieving the scientific goals of the Nuclear Physics program, including the continuation of the Lattice Gauge Quantum ChromoDynamics initiative with HEP.	+1,148
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
FY 2007 funding allows for enhanced efforts in the most promising areas for progress in nuclear physics with terascale computing capabilities.	+1,015
Total, Theory Research	**+5,374**
Nuclear Data Activities	
FY 2007 funding is increased ($+820,000) compared to the FY 2006 level, which allows for the recruitment of skilled personnel that are needed to maintain the Nation's nuclear data base. Funding ($+1,000,000) is provided for Nuclear Data activities which are also relevant to the design of next generation nuclear reactors.	+1,820
Total Funding Change, Nuclear Theory	**+7,194**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Construction			
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	—	—	7,000
07-SC-02, Electron Beam Ion Source, BNL	—	—	7,400
06-SC-02, Electron Beam Ion Source (PED), BNL	—	1,980	120
Total, Construction	—	1,980	14,520

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 2005	FY 2006	FY 2007
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	**—**	**—**	**7,000**

Funding is requested for PED for the 12 GeV CEBAF Upgrade (PED TEC ~$21M). The upgrade was identified in the 2002 NSAC LRP as one of the highest priorities for the Nation's nuclear science program, is a near-term priority in the SC 20-Year Facilities Outlook, and has obtained Mission Need approval. The upgrade will enable scientists to address one of the greatest mysteries of modern physics—the mechanism that “confines” quarks together. The project is preparing for a CD-1 review in FY 2006. Findings of a DOE Office of Project Assessment Review in FY 2005 which evaluated project plans, proposed performance and cost and schedule profiles are reflected in the FY 2007 budget request.

07-SC-02, Electron Beam Ion Source, BNL	**—**	**—**	**7,400**

Funds are provided to begin construction of the Electron Beam Ion Source (EBIS) project with a preliminary estimated TEC of $13,700,000 and TPC of $14,800,000 and completion in 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 will contribute an additional $4,500,000 above the DOE TPC. Findings of a Technical, Cost, Schedule and Management Review conducted in FY 2005 were utilized in the formulation of the FY 2007 budget request.

06-SC-02, Electron Beam Ion Source (PED), BNL	**—**	**1,980**	**120**

PED funding was reduced by $20,000 as a result of the FY 2006 rescission. 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. EBIS has received CD-0 and CD-1 approval, and is preparing for CD-2.

Total, Construction	**—**	**1,980**	**14,520**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	
Support is provided for project engineering and design for the 12 GeV CEBAF Upgrade.	+7,000
07-SC-02, Electron Beam Ion Source, BNL	
Funds are provided to initiate construction of the Electron Beam Ion Source (EBIS) to replace the aging Tandem Van de Graaff as the heavy-ion source for the RHIC complex.	+7,400
06-SC-02, Electron Beam Ion Source (PED), BNL	
Project engineering and design (PED) funds decrease consistent with the planned profile.	-1,860
Total Funding Change, Construction	**+12,540**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Plant Projects	7,407	7,342	7,870
Accelerator Improvements Projects	6,917	4,363	6,200
Capital Equipment	23,731	24,071	30,421
Total, Capital Operating Expenses	38,055	35,776	44,491

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Unappro-priated Balance
07-SC-01, 12 GeV CEBAF Upgrade (PED), TJNAF	21,000[a]	—	—	—	7,000	14,000
07-SC-02, Electron Beam Ion Source, BNL	13,700[b]	—	—	—	7,400	4,200
06-SC-02, Electron Beam Ion Source (PED), BNL	2,100[c]	—	—	1,980	120	—
Total, Construction			—	1,980	14,520	

[a] The full Total Estimated Cost (design and construction) ranges between $205,000,000 and $275,000,000; and the full Total Project Cost (design and construction) ranges between $225,000,000 and $300,000,000. These estimates are based on preliminary data and should not be construed as a project baseline. A CD-1 review is anticipated early in FY 2006.
[b] Includes the preliminary estimated TEC for design and construction. Design funding is in 06-SC-02. At the time of CD-1 approval, the full Total Estimated Cost (design and construction) ranges between $12,000,000 and $17,500,000. This estimate is based on preliminary data and should not be construed as a project baseline.
[c] 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 2005	FY 2006	FY 2007	Completion Date
STAR Time-of-Flight....................	4,800[a]	4,800[a]	—	—	2,376	2,424	FY 2009
GRETINA gamma-ray detector	18,200	17,000[b]	1,000	2,500	3,000	3,900	FY 2010
Fundamental Neutron Physics Beamline......................................	9,300	9,200[c]	1,000	1,200	1,900	1,500	FY 2010
PHENIX Vertex Tracker	4,500[d]	4,500[d]	—	—	—	2,000	FY 2009
Heavy Ion LHC Experiments	5,000[e]	5,000[e]	—	—	—	1,000	FY 2010
Electron Dipole Moment (EDM)...	18,300[f]	18,300[f]	—	—	—	1,300	FY 2013
Total, Major Items of Equipment....................................				3,700	7,276	12,124	

[a] A Technical, Cost, Schedule and Management Review was conducted in August 2005 to assess project plans and performance.

[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 estimated costs are preliminary and will be baselined at a Technical, Cost, Schedule and Management Review in the Spring 2006.

[e] CD-0 was approved in November 2005 with a preliminary TPC range of $5,000,000 - $16,000,000. The TEC is preliminary and will be baselined at CD-2.

[f] CD-0 was approved in November 2005 with a preliminary TPC range of $12,000,000 - $18,300,000. The TEC is preliminary and will be baselined at CD-2.

07-SC-01, Project Engineering and Design (PED), 12 GeV CEBAF Upgrade
Thomas Jefferson National Accelerator Facility, Newport News, Virginia

1. Significant Changes

This is the initial submission for project engineering and design funding for this project.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2007.......	1Q 2007	4Q 2009	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	21,000	11,000	—	32,000	—	32,000

4. Project Description, Justification, and Scope

This PED request provides Architect-Engineering (A-E) services for the preliminary and final design for the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade project at the Thomas Jefferson National Accelerator Facility (TJNAF). The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start or long-lead procurement items can be procured to support the 12 GeV CEBAF Upgrade schedule.

The CEBAF at the Thomas Jefferson National Accelerator Facility, or Jefferson Laboratory, is the world-leading facility in the experimental study of hadronic matter. The 12 GeV Upgrade of CEBAF directly supports the Office of Science Nuclear Physics' scientific thrusts. The upgrade is identified as a near-term priority in the Office of Science Twenty-Year Outlook. In addition, the Nuclear Science Advisory Committee (NSAC) in its 1996 Long Range Plan stated that "…the community looks forward to future increases in CEBAF's energy, and to the scientific opportunities that would bring." In its most recent 2002 Long Range Plan, NSAC recommends the 12 GeV Upgrade as one of its highest priorities for the Nuclear Physics program:

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[a] The estimates in Section 3 are for PED only. The full Total Estimated Cost (TEC design and construction) of the 12 GeV CEBAF Upgrade project at CD-0 ranges between $205,000,000 and $275,000,000, escalated from that presented at CD-0 to include increased costs associated with delays in the start of the project, and input from a July 2005 Independent Project Review of the Conceptual Design and associated plans. This estimate is based on pre-conceptual design and should not be construed as a project baseline.

> "We strongly recommend the upgrade of CEBAF at Jefferson Laboratory to 12 GeV as soon as possible. The 12 GeV upgrade of the unique CEBAF facility is critical for our continued leadership in the experimental study of hadronic matter. This upgrade will provide new insights into the structure of the nucleon, the transition between the hadronic and quark/gluon description of matter, and the nature of quark confinement."

The full scope of the proposed project is the accelerator upgrade, a new experimental hall and associated beam-line, and upgrades to the existing three experimental halls. DOE has recently conducted a thorough review of the scientific program of the new and upgraded experimental halls, to articulate the merit of the full accelerator and experimental proposed technical scope. TJNAF is exploring other non-DOE/NP sources of support for the construction of scientific equipment. A better understanding of non-DOE/NP funding contributions will be determined prior to the approval of the alternative selection and cost range (CD-1) and then finalized at the approval of the performance base-line (CD-2). This will provide important input into the final technical scope that will be established at CD-2. The preliminary estimated Total Project Cost (TPC) range is $225,000,000 to $300,000,000.

TJNAF is located on 162 acres in Newport News, Virginia. TJNAF was constructed over the period FY 1987-1995 for a cost of $513 million (Total Project Cost). CEBAF began operations in FY 1995 and is managed by the Southeastern Universities Research Association (SURA). Enhancing the capability of CEBAF is cost effective and builds upon existing infrastructure and capabilities. This project will reduce cost by using the existing systems, facilities, and experience at TJNAF instead of building a new facility with the same requirements at another location. The CEBAF upgrade alternative was chosen because it is more cost effective than building a new facility.

Compliance with Project Management Order

The project is being conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs presented in this data sheet are preliminary estimates for project engineering and design only. Plans call for a cost and schedule Performance Baseline to be developed during FY 2007 and approved by the Acquisition Executive at the completion of preliminary design (Critical Decision 2 – Approve Performance Baseline). The preliminary schedule for project Critical Decisions is as follows:

- Critical Decision – 0: Approve Mission Need—2Q FY 2004
- Critical Decision – 1: Approve Preliminary Baseline Range—2Q FY 2006
- Critical Decision – 2A: Approve Long Lead Baseline—4Q FY 2006
- Critical Decision – 3A: Approve Long Lead Procurements—3Q FY 2007
- Critical Decision – 2B: Approve Performance Baseline—4Q FY2007
- External Independent Review Final Report—3Q FY 2007
- Critical Decision – 3B: Approve Start of Construction—4Q FY 2008
- Critical Decision – 4: Approve Start of Operations—1Q FY 2014

5. Financial Schedule

(dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2007	7,000	7,000	5,600
2008	12,000	12,000	11,000
2009	2,000	2,000	4,000
2010	—	—	400
Total, Design	21,000	21,000	21,000

6. Details of Project Cost Estimate

Total Estimated Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Preliminary and Final Design	21,000	N/A

Other Project Costs

(dollars in thousands)

	Current Estimate	Previous Estimate
Conceptual Planning	11,000	N/A

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	—	5,600	11,000	4,000	400	—	—	21,000
OPC (Design)	7,455	2,500	1,045	—	—	—	—	11,000
Total, Project Costs (Design)	7,455	8,100	12,045	4,000	400	—	—	32,000

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

Design and inspection of the facilities and equipment will be by the operating contractor and Architect-Engineer (A-E) subcontractor as appropriate. A-E design services will be done by a combination of TJNAF and competitively bid lump sum contracts administered by the TJNAF. Preference will be given to procurements accomplished by fixed-price contracts awarded on the basis of competitive bidding. Project and design management, inspection, coordination, tie-ins, testing and checkout witnessing, and acceptance will be performed by the TJNAF operating contractor.

07-SC-02 Electron Beam Ion Source
Brookhaven National Laboratory, Upton, New York

1. Significant Changes

This is a new data sheet for construction funding beginning in FY 2007. Project engineering and design funding is included for this project in FY 2006 and FY 2007 under project number 06-SC-02.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2007.......	1Q FY 2006	4Q FY 2007	2Q FY 2007	2Q FY 2010	N/A	N/A

3. Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	13,700	1,100	N/A	14,800[a]	4Q FY 2006[b]	14,800[a]

4. Project Description, Justification, and Scope

This data sheet requests construction funding for the Electron Beam Ion Source (EBIS) project at Brookhaven National Laboratory (BNL). Project engineering and design (PED) funding is included for this project in FY 2006 and FY 2007 under project number 06-SC-02.

The flagship user facility at BNL is the Relativistic Heavy Ion Collider (RHIC), unique in the world for its ability to create a heretofore-unknown state of nuclear matter called quark-gluon plasma. The operation of RHIC supports the scientific mission of the DOE by providing a world-class facility for Nuclear Physics Research. The quark-gluon plasma is created through the collision of heavy ions accelerated to nearly the speed of light. This process is started at the RHIC pre-injector. The present pre-injector for heavy ions for RHIC uses the Tandem Van de Graaff, built around 1970. The beam is transported to the Booster via an 860 m long line.

The EBIS project will provide a new heavy ion pre-injector for RHIC based on a high charge state heavy ion source, a Radio Frequency Quadrupole (RFQ) accelerator, and a short Linear Accelerator (Linac). The highly successful development of an Electron Beam Ion Source at BNL now makes it possible to replace the present pre-injector that is based on electrostatic Tandems with a reliable, low maintenance Linac-based pre-injector.

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[a] The costs presented in this Project Data Sheet are preliminary estimates and should not be construed as a project baseline, and includes the costs for PED from project 06-SC-02. The Total Estimated Cost (design and construction), established at Critical Decision 0, ranged between $12,000,000 and $17,500,000; the Total Project Cost (design and construction) ranged between $16,000,000 and $19,500,000. NASA is contributing $4,500,000 to the estimated TPC of $19,300,000, thereby reducing the DOE contribution to $14,800,000.
[b] No construction funds will be used until the Performance Baseline has been validated.

Linac-based pre-injectors are presently used at most accelerator and collider facilities with the exception of RHIC, where the required gold beam intensities could only be met with a Tandem until the recent EBIS development. EBIS produces high charge state ions directly, eliminating the need for two stripping foils required with the Tandem. Unstable stripping efficiency of these foils is a significant source of luminosity degradation in RHIC. The high reliability and flexibility of the new Linac-based pre-injector will lead to increased integrated luminosity at RHIC and is an essential component for the long-term success of the RHIC facility. This new pre-injector based on an EBIS also has the potential for significant future intensity increases and can produce heavy ion beams of all species including uranium beams and could also be used to produce polarized ^{3}He beams.

The new RFQ and Linac are used to accelerate beams from EBIS to an energy sufficient for Booster injection. Injection into the Booster will be at the same location as is used for beams from the Tandem.

The new pre-injector will be installed in the lower equipment bay of the existing 200 MeV Linac Building. Modifications to this building will be required to provide an injection path into the Booster and house the new equipment.

In summary, the proposed new pre-injector offers the following advantages:

- The EBIS replaces the 35 year old Tandems with a modern, linac-based pre-injector
- The RFQ and linac technology is simpler, more modern and robust, and will require significantly less effort to maintain.
- The 860 meter long Tandem-to-Booster transport line will be replaced with a 30 to 40 meter transport system
- The EBIS eliminates current limitations on ion species. While injection from the Tandems must start with negative ions, the EBIS can produce any ion species.
- The single EBIS would allow pulse-to-pulse switching between any two species. This increased flexibility will provide the ability to meet the multiple, simultaneous needs of RHIC, NASA, and the Alternating Gradient Synchrotron (AGS). Presently, two tandems are needed for fast beam switching, while the new pre-injector will be able to switch species on a pulse-to-pulse basis.
- Beam stability will be improved with the elimination of stripping foils now required in the tandems.
- The addition of the EBIS pre-injector has the potential to reduce operations costs. The Tandem facility requires a staff of ~12 FTE's to support maintenance and a 24-hour shift rotation during operations. The linac-based pre-injector will run unattended at most times, as with the present proton linac, and will require a staff of ~3 FTE's to maintain.

If the new linac-based pre-injector is not built, upgrades to the Tandems will be required in order to ensure reliable long term operation for RHIC. Construction began for the Tandem Van de Graaff facility in 1966, and it was commissioned in 1970. Many of the Tandem systems are still 1960's technology, and those systems need to be modernized. Obsolete equipment would need to be replaced, and a computer-based control system installed. In addition, sufficient spares for some key components, such as accelerator tubes, would need to be purchased. The estimated fully-burdened cost of these required upgrades is ~$9,000,000. However, the retention, maintenance and modernization of the Tandem system would not provide the advantages of EBIS listed above.

The Electron Beam Ion Source (EBIS) project received CD-0 approval in the 4Q FY 2004 and CD-1 was approved in the 4Q FY 2005. Cost estimates have been improved through a recent bottoms-up cost estimate, an external technical review of the project, which was held in January 2005, and an internal cost review held in February 2005. A DOE review of technical scope, cost, schedule and management was held in July 2005 prior to CD-1 approval.

The replacement of the existing ion source at Brookhaven National Laboratory (BNL) with the proposed EBIS offers additional capabilities to NASA in the operation of the NASA Space Radiation Laboratory (NSRL) at BNL. NASA is providing a total of $4,500,000 in funding, reducing the Total Project Cost of EBIS to DOE, in order to accelerate the project profile and decrease project duration. The Critical Decision Schedule shown below reflects the accelerated schedule in comparison to that proposed at CD-0.

Compliance with Project Management Order

The project will be conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs presented in this data sheet are preliminary estimates for project engineering design and construction. The performance baseline is expected to be validated by the 4Q FY 2006. No construction funds will be used until the Performance Baseline has been validated. The preliminary schedule for project Critical Decisions is as follows:

- Critical Decision – 0: Approve Mission Need—4Q FY 2004
- Critical Decision – 1: Approve Preliminary Baseline Range—4Q FY 2005
- Critical Decision – 2: Approve Performance Baseline—4Q FY 2006
- External Independent Review Final Report—4Q FY 2006
- Critical Decision – 3: Approve Start of Construction—1Q FY 2007
- Critical Decision – 4: Approve Start of Operations—2Q FY 2010

Critical Decision 2 establishing the Performance Baseline is planned for 4Q FY 2006. No construction funds will be used until the Performance Baseline has been validated. The project schedule is being accelerated in order to realize cost savings in RHIC operations sooner and to take advantage of NASA's contributions to reduce the total cost of the project to DOE. NASA funding contributions are intended to complete the project in a more timely manner, consistent with NASA mission requirements.

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
2006	1,980[a]	1,980	1,900
2007	120[c]	120	200
Total, Design PED (06-SC-02)	2,100	2,100	2,100
Construction			
2007	7,400	7,400	5,800
2008	4,200	4,200	4,900
2009	—	—	900
Total, Construction	11,600	11,600	11,600
Total DOE TEC	13,700	13,700	13,700

6. Details of Project Cost Estimate

Total Estimated Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Preliminary and Final Design (PED 06-SC-02)	2,100	3,500
Construction Phase		
Site Preparation	695	N/A
Equipment	8,360	N/A
Contingency	2,545	N/A
Total, Construction	11,600	N/A
Total, DOE TEC	13,700[b]	N/A

Other Project Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Conceptual Planning	200	200
R&D	500[c]	—
Start-up	250	—
Contingency for OPC other than D&D	150	—
Total, DOE OPC	1,100	200

[a] The FY 2006 PED funding was reduced by $20,000 as a result of the FY 2006 rescission. This reduction is restored in FY 2007 to maintain the TEC and project scope.
[b] NASA is proposing to provide an additional $3,900,000 in TEC construction funding.
[c] NASA is proposing to provide an additional $600,000 in OPC funding.

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC(Design)	1,900	200	—	—	—	—	—	2,100
TEC (Construction)	—	5,800	4,900	900	—	—	—	11,600
OPC Other than D&D	800	—	100	200	—	—	—	1,100
Total, Project Costs	2,700	6,000	5,000	1,100	—	—	—	14,800

8. Related Operations and Maintenance Funding Requirements

Start of Operation or Beneficial Occupancy (fiscal quarter)	2Q FY 2010
Expected Useful Life (number of years)	25
Expected Future start of D&D for new construction (fiscal quarter)	1Q FY 2035

(Related Funding Requirements)

Costs to operate EBIS are included in the RHIC Operations budget and they are not considered incremental costs.

9. Required D&D Information

This upgrade project will not create any new building square footage, and thus is not subject to the "one-for-one" replacement requirement.

10. Acquisition Approach

The Acquisition Strategy was approved in 4Q FY 2005 with CD-1 approval.

06-SC-02, Project Engineering and Design (PED), Electron Beam Ion Source, Brookhaven National Laboratory, Upton, New York

1. Significant Changes

The Electron Beam Ion Source (EBIS) project received CD-0 approval in the 4Q FY 2004 and CD-1 was approved in the 4Q FY 2005. Cost estimates have been improved through a recent bottoms-up cost estimate, an external technical review of the project, and an internal cost review held in February 2005. As a result, the total estimated cost for PED has decreased from $3,500,000 to $2,100,000. A DOE review of technical scope, cost, schedule and management was held in July 2005 prior to CD-1 approval.

Construction funding is requested for EBIS in FY 2007 under project number 07-SC-02.

2. Design, Construction, and D&D Schedule

(fiscal quarter)

	Preliminary Design start	Final Design Complete	Physical Construction Start	Physical Construction Complete	D&D Offsetting Facilities Start	D&D Offsetting Facilities Complete
FY 2006.......	1Q FY 2006	4Q FY 2007	N/A	N/A	N/A	N/A
FY 2007.......	1Q FY 2006	4Q FY 2007	N/A	N/A	N/A	N/A

3. Baseline and Validation Status[a]

(dollars in thousands)

	TEC	OPC, except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2006	3,500	200	—	3,700	—	3,700
FY 2007	2,100	800	—	2,900	—	2,900

4. Project Description, Justification, and Scope

This PED request provides for Architect-Engineering (A-E) services for the preliminary and final design for the Electron Beam Ion Source (EBIS) project. The design effort will be sufficient to assure project feasibility, define the scope, provide detailed estimates of construction costs based on the approved design, working drawings and specifications, and provide construction schedules including procurements. The design effort will ensure that construction can physically start and long-lead procurement items can be procured in FY 2007 when construction funding is first requested.

The flagship user facility at Brookhaven National Laboratory (BNL) is the Relativistic Heavy Ion Collider (RHIC), unique in the world for its ability to create a heretofore-unknown state of nuclear matter called quark-gluon plasma. The operation of RHIC supports the scientific mission of the DOE by providing a world-class facility for Nuclear Physics Research. The quark-gluon plasma is created through the collision of heavy ions accelerated to nearly the speed of light. This process is started at the

[a] The estimates in Section 3 are for PED only. The full Total Estimated Cost (design and construction) of the EBIS project at CD-0 ranged between $12,000,000 and $17,500,000; the full Total Project Cost at CD-0 ranged between $16,000,000 to $19,500,000. This estimate is based on pre-conceptual design and should not be construed as a project baseline.

RHIC pre-injector. The present pre-injector for heavy ions for RHIC uses the Tandem Van de Graaff, built around 1970. The beam is transported to the Booster via an 860 m long line.

The EBIS project will provide a new heavy ion pre-injector for RHIC based on a high charge state heavy ion source, a Radio Frequency Quadrupole (RFQ) accelerator, and a short Linear Accelerator (Linac). The highly successful development of an Electron Beam Ion Source at BNL now makes it possible to replace the present pre-injector that is based on electrostatic Tandems with a reliable, low maintenance Linac-based pre-injector.

Compliance with Project Management Order

The project is being conducted in accordance with the project management requirements in DOE Order 413.3 and DOE Manual 413.3-1, Program and Project Management for the Acquisition of Capital Assets. The project costs presented in this data sheet are preliminary estimates for project engineering and design only. Plans call for a cost and schedule Performance Baseline to be developed during FY 2006 and approved by the Acquisition Executive at the completion of preliminary design (Critical Decision 2 – Approve Performance Baseline). The preliminary schedule for project Critical Decisions is as follows:

- Critical Decision – 0: Approve Mission Need—4Q FY 2004
- Critical Decision – 1: Approve Preliminary Baseline Range—4Q FY 2005
- Critical Decision – 2: Approve Performance Baseline—4Q FY 2006
- External Independent Review Final Report—4Q FY 2006
- Critical Decision – 3: Approve Start of Construction—1Q FY 2007
- Critical Decision – 4: Approve Start of Operations—2Q FY 2010

5. Financial Schedule

	(dollars in thousands)		
	Appropriations	Obligations	Costs
Design by Fiscal Year			
2006	1,980[a]	1,980	1,900
2007	120[b]	120	200
Total, Design	2,100	2,100	2,100

[a] The FY 2006 PED funding was reduced by $20,000 as a result of the FY 2006 rescission. This reduction is restored in FY 2007 to maintain the TEC and project scope.

6. Details of Project Cost Estimate

Total Estimated Costs

	(dollars in thousands) Current Estimate	Previous Estimate
Preliminary and Final Design	2,100	3,500

Other Project Costs

	(dollars in thousands) Current Estimate	Previous Estimate
Conceptual Planning	200	200
R&D	500[a]	—
Contingency for OPC other than D&D	100	—
Total, OPC	800	200

7. Schedule of Project Costs

(dollars in thousands)

	Prior Years	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	Outyears	Total
TEC (Design)	1,900	200	—	—	—	—	—	2,100
OPC (Design)	800	—	—	—	—	—	—	800
Total, Project Costs (Design)	2,700	200	—	—	—	—	—	2,900

8. Related Operations and Maintenance Funding Requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

[a] Cost estimates and definition of project tasks have been improved through recent budget and technical reviews, which have led to a refined definition of the R&D needs for the project and more refined definitions of tasks as correlating to R&D vs. PED activities. The previous estimate for OPCs did not include planned R&D efforts, which are now articulated in this Project Data Sheet.

10. Acquisition Approach

Design and inspection of the facilities and equipment will be by the operating contractor and Architect-Engineer (A-E) subcontractor as appropriate. A-E design services will be done by a combination of BNL and competitively bid lump sum contracts administered by the BNL. To the extent feasible, procurements will be accomplished by fixed-price contracts awarded on the basis of competitive bidding. Project and design management, inspection, coordination, tie-ins, testing and checkout witnessing, and acceptance will be performed by the BNL operating contractor.

An approved Acquisition Strategy was generated in 4Q FY 2005 and assessed as part of the CD-1 approval process.

Fusion Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Fusion Energy Sciences					
Science	148,494	158,507	-1,585[a]	156,922	154,213
Facility Operations	89,733	104,582	-1,046[a]	103,536	121,555
Enabling R&D	28,720	27,461	-275[a]	27,186	43,182
Total, Fusion Energy Sciences	266,947[b]	290,550	-2,906	287,644	318,950

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. FES is pursuing this effort through collaborations among U.S. universities, industry, national research laboratories, and the international fusion community.

Benefits

Fusion is the energy source that powers the sun and stars. In the fusion process, forms of the lightest atom, hydrogen, fuse together to make helium in a very hot and highly charged gas or plasma. In the process, tremendous amounts of energy are produced. Fusion could play a key role in U.S. long-term energy plans and independence because it offers the potential for plentiful, safe and environmentally benign energy. The hydrogen isotopes deuterium and tritium, the fundamental fuel for a fusion reaction, are derived from sources as common and abundant as sea water and the earth's crust. Besides the advantages of an abundant fuel supply, the fusion process would produce little to no carbon emissions. A fusion power plant could be designed to shut down easily, have only short-lived radioactivity, and produce manageable radioactive waste. A science-based approach to fusion offers the most deliberate path to commercial fusion energy and is advancing our knowledge of plasma physics and associated technologies, yielding near-term benefits in a broad range of scientific disciplines. Examples include plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative materials coatings, space propulsion, a neutron source for the detection of explosives and highly enriched uranium for homeland security, and the efficient destruction of chemical and radioactive wastes.

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.
[b] Total is reduced by $2,207,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005; $6,211,000, which was transferred to the SBIR program; and $745,000, which was transferred to the STTR program.

Strategic and Program Goals

The Department's Strategic Plan identifies four strategic goals (one each for defense, energy, science, and environmental aspects of the DOE mission) plus seven general goals that tie to the strategic goals.

The FES program supports the following goal:

Science Strategic Goal
General Goal 5, World-Class Scientific Research Capacity: Provide world-class scientific research capacity needed to: ensure the success of Department missions in national and energy security; advance the frontiers of knowledge in physical sciences and areas of biological, medical, environmental, and computational sciences; or provide world-class research facilities for the Nation's science enterprise.

The FES program has one program goal which contributes to General Goal 5 in the "goal cascade":

Program Goal 05.24.00.00: 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 Program Goal 05.24.00.00 (World-Class Scientific Research Capacity)

The FES program contributes to this goal 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 Fusion Energy Sciences 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, as well as to identify those configurations that are most suitable for a fusion reactor; (5) investigating non-neutral plasma physics 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 university devices 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 years) 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 General and Program Goal

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.24.00.00, Bring the Power of the Stars to Earth (Fusion Energy Sciences)	266,947	287,644	318,950

Status of International ITER Negotiations and U.S. Policy and Budget Activities

The FES program is also pushing the boundaries in large scale international scientific collaboration. With the support of a Presidential negotiating mandate, FES is actively leading a U.S. effort to provide manpower and components as in-kind contributions in the 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. Negotiations continued throughout the Fall of 2005, which led to the ITER parties (a) approving and welcoming the designated Director General Nominee chosen to lead the ITER organization, (b) approving and welcoming India into the ITER negotiations as a full non-host ITER party, and (c) completing the text of the draft ITER Agreement. In completing the text of the ITER Agreement, it was determined that the international ITER Organization management structure will include the following critical positions: the Director General will provide overall leadership, the Principal Deputy Director General will provide the project management under the direction of the Director General, and multiple Deputy Directors-General will fulfill key management positions in construction, procurement, science, administration, regulatory, quality assurance, and other functional areas. It was agreed by the ITER parties that each participating party will hold at least one of these management positions. The Director General will propose his management structure to the ITER Council for its approval. It is anticipated that these positions will be filled by the time the United States completes the CD-1 cost and schedule range decision, planned for September 2006.

During the negotiations and following the acceptance of India as a full, non-host party, a revised allocation of hardware deliverables from each Party, including India, was agreed upon. Collectively, these two decisions enable all the ITER Parties to accomplish the originally planned ITER construction scope of work and, in addition, provide a contingency for the shared activities at the ITER site, such as design, system integration, provision of infrastructure and installation of hardware. The provision for such contingency is consistent with sound project management principles. 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, like the United States, what was previously a 10% share of a total, that excluded contingency for the site activities, now becomes about 9.1% of the ITER hardware, personnel and cash plus contingency for the site activities. The corresponding host share is about 45.4%.

Given the critical advances accomplished in 2005, it is the objective of the international ITER parties involved to obtain the negotiators' acceptance of the draft ITER Agreement by early 2006 indicating the end of the negotiations. The ITER Agreement, including various supporting documents, is key to the legal understanding and organization of the ITER Project. It is the collection of these documents that is hereafter referred to as the ITER Agreement. In accordance with the Energy Policy Act of 2005, and as determined during the Fall 2005 ITER negotiations, the ITER Agreement directly addresses the following EPAct requirements. Accordingly, the ITER Agreement:

(i) clearly defines the U.S. financial contribution to construction and operations (as well as deactivation and decommissioning), as well as any other project costs associated with a project,
(ii) ensures that the share of high-technology components of ITER that are manufactured in the United States is at least proportionate to the U.S. financial contribution to ITER,
(iii) ensures, by virtue of the in-kind contribution procurement approach, that the United States will not be financially responsible for cost overruns in components manufactured by other ITER parties,
(iv) guarantees the United States full access to all data generated by ITER,
(v) enables U.S. researchers to propose and carry out an equitable share of experiments on ITER,
(vi) provides the United States with a role in all collective decision-making related to ITER, and
(vii) describes and defines the process for discontinuing and decommissioning ITER and the U.S. role in that process.

Once the negotiators have initialed the final report of the negotiations, and the Agreement has been available to the Congress for 120 days, the next step, assuming no objection from the Congress, will be to obtain governmental signatures on the completed ITER Agreement around mid-2006, by all ITER parties, thereby leading to a multilateral commitment for ITER. The final step is the ratification or formal acceptance of the documents which then allows the ITER Agreement to enter into force and the ITER Organization to be established. The U.S. participation in ITER, as a non-host participant, is being accomplished through the "U.S. Contributions to ITER" Major Item of Equipment (MIE) project. In support of ITER and the U.S. Contributions to ITER MIE, FES is placing increased emphasis on its national burning plasma program—a critical underpinning to the fusion science in ITER. FES plans to enhance burning plasma research efforts across the U.S. domestic fusion program, including the following elements:

- 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;
- Carrying out 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.

The U.S. Contributions to ITER project is being managed by the U.S. ITER Project Office (USIPO), established as a Princeton Plasma Physics Laboratory (PPPL)/Oak Ridge National Laboratory (ORNL) partnership. The management structure for the USIPO includes the Project Manager, managers for Planning Control and Project Engineering, Chief Scientist, Team Leaders in the areas of Design Integration, Magnets, Diagnostics, Heating and Fueling, Tritium, Plasma Facing Components, and dedicated cost and procurement personnel.

Since the establishment of the U.S. ITER Project Office in July 2004, preliminary cost and schedule ranges have been prepared, reviewed, and revised to reflect resolution of uncertainties associated with the international ITER Project. In July 2005, the Deputy Secretary of Energy approved DOE 413.3 Critical Decision 0, Mission Need for ITER. Project management documentation required by DOE Order 413.3 has been updated. The Project Office is preparing for approval of Critical Decision 1, Approve Alternative Selection and Cost Range, in September 2006 and Critical Decision 2, Approve

Performance Baseline, in September 2007. The FY 2006 Appropriation provided for a slower start for the U.S. Contributions to ITER project consistent with the delay in site selection. As a result of this slower start, the funding profile has been altered from the one provided with the FY 2006 Budget by shifting funds formerly intended for FY 2006 and FY 2007 into FY 2008 and beyond. This revised funding profile should still allow the U.S. to fulfill its non-host obligations to the international project, a minimum contribution of any ITER party during the phase of construction.

The FY 2007 request provides for the continuation of the U.S. Contributions to ITER MIE project. The Total Project Cost remains unchanged from FY 2006 and is summarized below in the Significant Program Shifts section, Total Estimated Costs (TEC) in the Facilities Operations subprogram, and Other Project Costs (OPC) in the Enabling R&D subprogram. There is a necessary shift indicated in the FY 2007 TEC and OPC categories to accommodate domestic and international project priorities under the revised funding profile.

The Energy Policy Act of 2005 Sec. 972(c)(5)(C) requires the Secretary of Energy to provide "a report describing how United States participation in the ITER will be funded without reducing funding for other programs in the Office of Science (including other fusion programs)…" The Department's FY 2007 budget provides for healthy increases for all programs within the Office of Science and supports the ITER request of $60,000,000 almost entirely from new funds in the Fusion Energy Sciences (FES) budget request.

The Director of the Office of Science has stated that the FES program in the Office of Science will reasonably bear at least some of the cost of building ITER from within its budget and that ITER will not unduly harm funding of other Office of Science research programs. The Department expects that the $1.122 billion ITER funding profile could have some effect on the overall allocation of funds, both within the FES program and within the Office of Science, in future budgets. This has been and will continue to be the standard practice for funding large, capital-intensive projects within DOE. Nevertheless, as demonstrated by this FY 2007 request, the Office of Science can fund ITER while maintaining healthy funding for other research programs.

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 community-based U.S. Burning Plasma Organization established in 2005 for this purpose.

The Energy Policy Act (EPAct), July 2005, 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 the 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 U.S. fusion program. The EPAct requires that this plan be developed in consultation with FESAC, and reviewed by the National Academy of Sciences. In FY 2006, DOE has initiated steps to develop a plan for the participation of U.S. scientists in ITER.

As a first step, FES asked the U.S. fusion community to establish a Burning Plasma Organization (USBPO) to coordinate and facilitate a coherent burning plasma related work program and ITER supporting research. FES appointed the Director of USBPO in May 2005 to lead this effort. 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. In addition, the workshop was also charged to identify what issues remain to be resolved for successful burning plasma experiments in ITER, what contributions can/should the U.S. fusion program make to resolve these issues, and how should the USBPO be structured to best help the community make these contributions.

The USBPO, working together with the Fusion Energy Sciences Advisory Committee (FESAC), will produce a 'Plan for U.S. Scientific Participation in ITER' with technical details in 2006. This Plan, which will be a dynamic tool, will guide the U.S. preparations for the ITER experiments in the ongoing U.S. fusion program, and will contribute to the detailed planning by all ITER Parties of the ITER experiments. The Plan will be reviewed by the National Academy of Sciences and updated every three years to account for new technical developments in fusion research.

Annual Performance Results and Targets

FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Program Goal 05.24.00.00 (World-Class Scientific Research Capacity)					
Science[a]					
N/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 will measure 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 will inject 2 MW of neutral power in the counter direction on DIII-D and begin physics experiments.	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.
N/A	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 will simulate 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 will simulate nonlinear plasma edge phenomena using extended MHD codes with a resolution of 40 toroidal modes.	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.

[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.

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FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Results	FY 2006 Targets	FY 2007 Targets
Facility Operations					
Kept deviations in weeks of operation for each major facility within 10% of the scheduled weeks. [met goal]	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%.	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 project baselines; successfully completed within cost and in a safe manner all TFTR decontamination and decommissioning activities. [met goal]	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%.	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.

Means and Strategies

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

The science and the technology of fusion have progressed to the point that the next major research step is the exploration of the physics of a sustained plasma reaction in a burning plasma physics experiment. ITER is the focal point of sustained burning plasma fusion research around the world, and the Administration has joined the negotiations to conduct this experiment. 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, and experimental physics. Longer range technology activities have been redirected to support preparations for the realization of the burning plasma device 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 South Korea on the design of diagnostics for their long-pulse, superconducting, advanced tokamak (KSTAR). The strengthened relationships resulting from these international collaborations can foster scientific advancement and facilitate shared science worldwide. These collaborations 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 2004, the United States began participating in the ITER Transitional Arrangements activities, which is an international framework established during the earlier ITER Engineering Design Activities to prepare for the international project and the Parties' "in-kind" equipment fabrication for ITER during the period of negotiations for the ITER Agreement. In addition, we have established a community-based Burning Plasma Organization to stimulate and coordinate ITER-related research within the U.S. fusion program.

In FY 2007, funding for the U.S. Contributions to ITER MIE project is identified as Total Estimated Costs (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, and cash for the U.S. share of common expenses such as infrastructure, hardware assembly, and installation. The OPC funding is provided for R&D and design in support of equipment—mainly heating, current drive and diagnostics—that will be provided by the U.S. to ITER. The results of this R&D and design are applicable to ITER and other burning plasma experiments. In addition, there is related support for both the ITER physics basis and the preparations for science and technology research to be conducted using ITER. This related support comes from a broad spectrum of science and technology activities within the FES program such as the experimental research from existing facilities, as well as the fusion plasma theory and computation activities, and is not part of the MIE project.

In the area of high energy density physics, OFES will continue to seek to leverage NNSA's program efforts and pursue non-defense high energy density physics experiments on their facilities. Through an interagency process, collaboration in this area will be extended to other agencies as well.

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 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 process on a 5-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, C-Mod at MIT, and NSTX at PPPL) had such peer reviews in the April-June 2003 time frame. Checkpoint reviews at the 3-year point provide interim assessment of program quality. These checkpoint reviews for the three facilities will be held in 2006. Program Advisory Committees for the major facilities provide annual or semi-annual feedback on assessments of 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; 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:

(1) changing mission needs as described by the DOE and SC mission statements and strategic plans;
(2) scientific opportunities as determined, in part, by proposal pressure and scientific workshops;
(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 (NAS);
(4) unanticipated failures in critical components of scientific facilities that cannot be mitigated in a timely manner; and
(5) 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 implemented a tool, the PART Assessment, 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 Fusion Energy Sciences (FES) program has incorporated feedback from OMB into the FY 2007 budget request and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the FES program a relatively high score of 82% overall which corresponds to a rating of "Moderately Effective." This score is attributable to the use of standard management practices in FES. The assessment found that FES has developed a limited number of adequate performance measures which are continued for FY 2006. 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 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 Report. In response to PART findings, FES 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 first COV report is available on the web (http://www.ofes.fusion.doe.gov/more_html/fesac/committeeofvisitors.pdf), as is the FES response to this report (http://www.ofes.fusion.doe.gov/more_html/fesac/covlettertohazeltine.pdf). The second COV report is also available on the web (http://www.ofes.fusion.doe.gov/more_html/fesac/cov_final.pdf), as is the FES response (http://www.ofes.fusion.doe.gov/more_html/fesac/ofesresponseto2ndcov.pdf).

OMB found that the FES budget was not sufficiently aligned with scientific program goals and that a science-based strategic plan for the future of U.S. fusion research within an international context needed to be developed. In response, FESAC was tasked to write a report that identified and prioritized scientific issues and respective campaign strategies. An interim report was completed in July 2004 and a final report was completed in April 2005. This report forms the basis of an FES strategic plan which also includes efforts in ITER, and was completed in September 2005.

For the FY 2007 Budget, OMB has developed PARTWeb—a new interface for PART that facilitates collaboration between agencies and OMB. PARTWeb will link to the http://ExpectMore.gov website and will improve public access to PART assessments and follow up actions. For 2006 there are three actions for Fusion Energy Sciences.

- Developing strategic and implementation plans in response to multiple Congressional requirements.
- Implementing the recommendations of expert review panels, especially two major National Academies studies, as appropriate.
- Re-engaging the advisory committee in a study of how the program could best evolve over the coming decade to take into account new and upgraded international facilities.

This budget request is the first important response to Congressional language regarding ITER and the domestic fusion energy program. FES is actively working to implement recommendations as appropriate. Improvements will be posted at http://www.sc.doe.gov/measures/FY06.html

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, in which the temperature and density approach the conditions needed to allow the nuclei of two low-mass elements, e.g., hydrogen isotopes deuterium and tritium, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. There are two leading methods of confining the fusion plasma—magnetic confinement, in which strong magnetic fields constrain 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, FES is able to access an important research base from which the physics of the target-driver interaction can be studied in the hopes of finding a promising path to practical fusion energy.

The Fusion Energy Sciences program activities are designed to address the scientific and technology issues facing both magnetic and inertial fusion. The FESAC Priorities Panel has identified six scientific campaigns, or topical areas, to organize these scientific and technical issues in both magnetic and inertial fusion 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 issues in both magnetic and inertial fusion. The panel has identified 15 fundamental scientific questions, 1-3 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.

These 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 role of FES is management of resources and technical oversight of the program. FES has established an open process for obtaining scientific input for major decisions, such as the 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 Director of the Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research or related fields. The Director of the Office of Science charges the Committee to provide advice and recommendations on various issues of concern to the fusion energy sciences program. The Committee conducts its business in public meetings, and submits reports with advice and recommendations to the Department.

A variety of other committees and groups provide input to program planning. Ad hoc activities by fusion researchers provide a forum for community debate and formation of consensus. The President's Council of Advisors on Science and Technology (PCAST) has also examined the fusion program on several occasions, as has the Secretary of Energy Advisory Board. The National Research Council, whose Plasma Physics Committee serves as a continuing connection to the general plasma physics community, recently carried out an assessment of the Department of Energy's Fusion Energy Sciences' strategy for addressing the physics of burning plasmas. In addition, the extensive international collaborations carried out by U.S. fusion researchers provide informal feedback regarding the U.S. program and its role in the international fusion effort. These sources of information and advice are integrated with peer reviews of research proposals and, when combined with high-level program reviews and assessments, provide the basis for prioritizing program directions and allocations of funding.

Program Advisory Committees (PACs) serve an extremely important role in providing guidance to facility directors in the form of program review and advice regarding allocation of facility run-time. These PACs are 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.

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.

Program Reviews

The peer review process is used as the primary mechanism for evaluating proposals, assessing progress and quality of work, and for initiating and terminating facilities, projects, and research programs. This policy applies to all university and industry programs funded through grants, national laboratory programs funded through Field Work Proposals (FWPs), and contracts from other performers. Peer review guidelines for FES derive from best practices of government organizations that fund science and technology research and development, such as those documented in the General Accounting Office report, "Federal Research: Peer Review Practices at Federal Science Agencies Vary" (GAO/RCED-99-99, March 1999), as well as more specifically from relevant peer review practices of other programs in the Office of Science.

Merit review in FES is based on peer evaluation of proposals and performance in a formal process using specific criteria and the review and advice of qualified peers. In addition to the review of the scientific quality of the programs provided by the peer review process, FES also reviews the 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, motivated in response to PART findings, involves charging FESAC to establish a Committee of Visitors (COV) to review program management practices every three to four years on a rotating basis for the following program elements: (1) theory and computation, (2) innovative confinement concepts, high energy density physics, and general plasma science, and (3) tokamak research and enabling R&D. In April 2005, the second COV completed its review of the research portfolio and peer review process for the FES innovative confinement concepts, high energy density physics, and general plasma science programs. It concluded that these FES-supported research programs were of high quality and that the biggest concern was flat budgets for these programs. Further, the COV found that OFES program managers are serious, conscientious, and dedicated, and are doing a good job overall. Prior to their on-site review, the COV did a survey of the fusion community and found that this community agrees with these findings. With respect to recommendations, the COV suggested that OFES should (1) develop a uniform, clearly stated, rebuttal procedure, (2) implement several minor changes in the peer review process to improve the accuracy of the final funding decisions, and (3) improve the uniformity and consistency of the information contained in the proposal files. All of these recommendations are being adopted now for proposals requesting FY 2006 funds.

Planning and Priority Setting

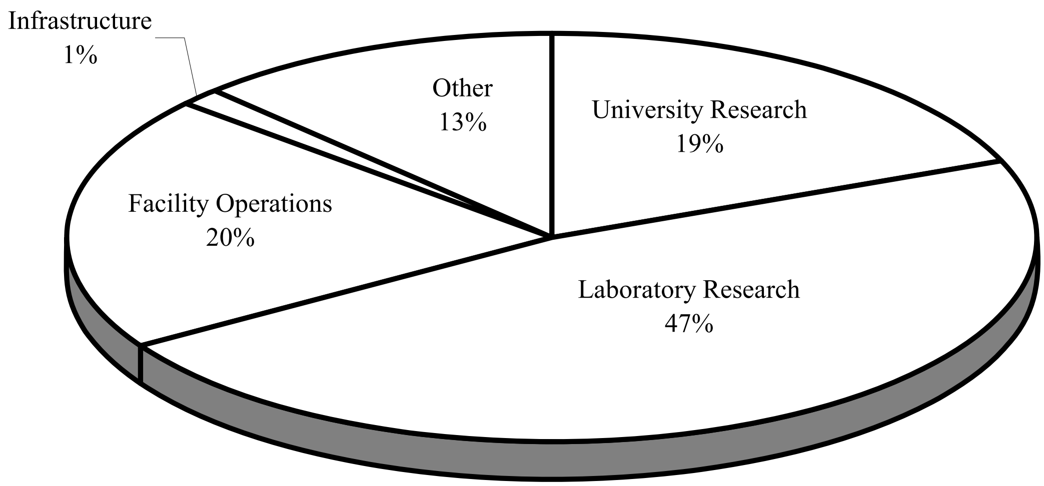
The FESAC carries out an invaluable role in the fusion program by identifying critical scientific issues and providing advice on intermediate and long-term goals to address these issues. As described above, FESAC has recently assisted the Department and the fusion community in establishing priorities 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 two major facilities, located at a national laboratory (Princeton Plasma Physics Laboratory), and a private sector institution (General Atomics [GA]). In addition to a major research facility at Massachusetts Institute of Technology (MIT), 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 2007



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 8 states. The three major facilities are operated by the hosting institutions but are configured with national research teams made up of local scientists and engineers, and researchers from other institutions and universities, as well as foreign collaborators.

- **University Research**

  University researchers continue to be a critically important component of the fusion research program and are responsible for training graduate students. University research is carried out on the full range of scientific and technical topics of importance to fusion. 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 University of California, Los Angeles (UCLA) that is jointly funded by DOE and 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 review 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 Principal Young Investigator 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 2007 request is $318,950,000, 10.9% over the FY 2006 Appropriation. The FY 2007 budget continues the redirection of the fusion program to prepare for and participate in the international ITER project. The redirection will require modest reductions in several program elements which are primarily not directly related to ITER.

Experimental research on tokamaks is continued, with increasing emphasis on physics issues of interest to the ITER project. The research and facility operations funding for the three major facilities will increase by $4,217,000 from the FY 2006 level. Operations at the largest facility, DIII-D, will increase from 7 weeks in FY 2006 to 12 weeks in FY 2007, while operations at C-Mod at MIT and NSTX at PPPL will each increase by one week over FY 2006, to 15 and 12 weeks respectively.

A new baseline was established in July 2005 for the National Compact Stellarator Experiment (NCSX), a joint ORNL/PPPL advanced stellarator experiment being built at PPPL. It results in a 14-month delay in the schedule with completion in July 2009 and a new TEC of $92,401,000. The FY 2007 request of $15,900,000 supports the new baseline.

An increase of $2,748,000 from the FY 2006 level in the Scientific Discovery through Advanced Computing (SciDAC) program will continue development of tools to facilitate international fusion collaborations and initiate development of an integrated software environment for multiphysics, multi-scale simulations of fusion systems. Within SciDAC, the Fusion Simulation Project is a major initiative involving plasma physicists, applied mathematicians, and computer scientists to create a comprehensive set of models of fusion systems, combined with the algorithms required to implement the models and the computational infrastructure to enable them to work together.

Other program shifts include: a reduction of $1,028,000 from the FY 2006 level in the Fusion Theory program and thereby the analytic theory capabilities of the program; a reduction of $3,907,000 from the FY 2006 level in the High Energy Density Physics program, resulting in a reduction in research in innovative approaches to high energy density physics (fast ignition and plasma jets), a reduction in research in heavy ion beam science, and the discontinuation of the Congressionally-directed, non-defense research at the Atlas pulsed power facility; a reduction of $3,616,000 from the FY 2006 level in the Plasma Technology and Materials Research programs in the Enabling R&D category, thereby eliminating research on a U.S. Test Blanket Module for use on ITER; and a reduction of $1,788,000 from the FY 2006 level in the Experimental Plasma Research program leading to reductions in all projects in the program.

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International Accomplishments:

Multilateral ITER negotiations continued in FY 2005 and in early FY 2006. Significant advances during the negotiations include: the selection of Cadarache, France, as the host site for ITER, designation and approval of the Director General Nominee, and approval and invitation for India to join the ITER negotiations as a full non-host participant. Equally important, the ITER parties completed the comprehensive process to finalize the draft ITER Agreement and supporting documentation, the collection of which covers all phases of the ITER project. In accordance with the requirements contained within the Energy Policy Act of 2005, Section 972(c)(3)(B)(i-vii), the draft ITER Agreement will finalize the current provisional list of equipment to be provided by each ITER Party, including India, and will finalize the mode of operation among the ITER parties and central project team during the construction, operation, and decommissioning phases of the ITER program. The process for finalizing the ITER Agreement included incorporation of input by topical area experts from each negotiating party including government officials, legal representatives, and fusion scientists, clarification and discussion among the representatives of each party and resolution of differences by the negotiators. Given the progress of the Fall 2005 negotiations among the ITER parties in resolving key issues, it is the objective of the international ITER parties to obtain the negotiators' acceptance of the draft ITER Agreement by early 2006 indicating the end of the negotiations. The next step will be to obtain governmental signatures on the completed ITER Agreement later in FY 2006, by all ITER parties, thereby leading to a multilateral commitment for ITER. During this time, representatives of the parties will address critical implementation decisions on detailed arrangements including assignment of management personnel.

U.S. ITER Project Accomplishments:

The Project Office, serving as the U.S. domestic agency for the international ITER Project, is responsible for the management of the U.S. contributions including hardware, personnel, and cash. 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, and revised to reflect resolution of uncertainties associated with the international ITER Project
- the Deputy Secretary of Energy approved DOE 413.3 Critical Decision 0, Mission Need for ITER
- project management documentation required by DOE Order 413.3 has been updated for the U.S. Contributions to ITER MIE project.

In FY 2005 and FY 2006, the Project Office has been preparing for approval of Critical Decision 1, Approve Alternative Selection and Cost Range, in September 2006 and Critical Decision 2, Approve Performance Baseline, in September 2007. This preparation includes monitoring and responding to activities associated with the international ITER Project. The schedule for Critical Decision 2 is dependent on the ability of the international ITER Organization establishing an efficient mode of operation and on their assessment of the current design and schedule for the international ITER Project—both of which affect the establishment of the performance baseline of the U.S. Contributions to ITER project.

The FY 2006 Appropriation provided for a slower start for the U.S. Contributions to ITER project. As a result of this slower start, the funding profile has been altered from the profile provided with the

FY 2006 Budget by shifting funds formerly intended for FY 2006 and FY 2007 into FY 2008 and beyond. This revised funding profile will still allow the U.S. to fulfill its non-host obligations to the international project, a minimum contribution of any ITER party during the phase of construction.

The FY 2007 request for the U.S. Contributions to ITER MIE project includes Total Estimated Costs (TEC) funding of $37,000,000 in the Facilities Operations subprogram and Other Project Costs (OPC) funding of $23,000,000 in the Enabling R&D subprogram. The annual Total Project Cost (TPC) profile for FY 2006 through FY 2014 is provided below, and the funding cap of $1,122,000,000 is maintained. The profile shows a more modest first two years than was contained in the FY 2006 President's Budget. The near-term reductions reflect the longer site selection process and allow for the U.S. to be more consistent with the other ITER parties in the pace of starting the long lead procurements, providing increased numbers of personnel to the ITER Organization, and providing cash for common expenses. The reductions in FY 2006 ($30,185,000) and FY 2007 ($86,000,000) relative to the levels shown in the FY 2006 budget are re-distributed in the outyears to allow for completion of the U.S. commitment as a non-host ITER participant. The profile and funding cap could change in the future if increases in escalation and/or fluctuations in the currency exchange rates occur. The profile is preliminary until the Director General Nominee and ITER Organization have achieved a standard mode of operation, and the baseline scope, cost, and schedule for the MIE project (CD-2) are established.

U.S. Contributions to ITER MIE Project

Annual Profile[a]

(budget authority in thousands)

Fiscal Year	Total Estimated Costs	Other Project Costs	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	1,500	210,000
2011	180,785	500	181,285
2012	130,000	—	130,000
2013	116,900	—	116,900
2014	30,000	—	30,000
Total	1,077,051	44,949	1,122,000

Estimated TEC, OPC, and TPC Costs

The Current Estimate in the table below is the same as the FY 2006 estimate and does not yet reflect the results of the December 2005 negotiations. The estimate is now being revised to incorporate the key results of the negotiations; i.e., India was accepted as a non-host partner, cost sharing was agreed upon, a revised allocation of hardware contributions was agreed upon, and a new contingency was agreed upon

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. In addition, shifts between OPC and TEC funding have been made consistent with the intentions of DOE 413.3 to provide for R&D and design in support of the MIE project. During FY 2006, several U.S. reviews are scheduled to validate the preliminary cost and schedule profile for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2006 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-2 planned for September 2007.

for the international ITER Organization. Based on the results of the negotiations, the fabrication and other project costs in the table will be reduced and the contingencies will be increased; however, the Total Project Cost will remain unchanged. After these revisions are reviewed in accordance with DOE project management procedures, the details will be available for the FY 2008 budget request.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Fabrication Costs		
Procurement of U.S. in-kind equipment (non-host contribution to ITER)	573,800	573,800
Installation of U.S. in-kind equipment	71,900	71,900
Assignment of U.S. scientists and engineers to ITER Org (non-host contribution to ITER)	87,300	87,300
Contribution of funds for support personnel at ITER Org (non-host contribution to ITER)	36,200	36,200
Operation of U.S. ITER Project Office including management, QA, procurement, etc.	123,600	123,600
Subtotal	892,800	892,800
Contingencies at approximately 16% of above costs	145,200	145,200
Total Estimated Costs (TEC)	1,038,000	1,038,000
Other Project Costs - Base Program R&D and Design Support for above tasks	68,000	68,000
Contingencies at approximately 24% of OPC costs	16,000	16,000
Total Other Project Costs (OPC)	84,000	84,000
Total Project Costs (TPC)	1,122,000	1,122,000

Related Annual Funding Requirements

The Current Estimate in the table below has been revised based upon the results of the December 2005 negotiations (i.e., agreement was reached on cost sharing during operations, deactivation and decommissioning), on the procedure for converting currencies into Euros, and on the 20 year period of annual contributions to the decommissioning fund in conjunction with ITER operations. It has been possible to make these revisions now because the changes are straightforward.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
FY 2014–FY 2033		
U.S. share of annual facility operating costs including commissioning, maintenance, repair, utilities, power, fuel, improvements, and annual contribution to decommissioning fund for period 2014 to 2033. Estimate is in year 2014 dollars.	55,700	58,300
FY 2034–FY 2038		
U.S. share of the annual cost of deactivation of ITER facility for period 2034–2038. Estimate is in year 2036 dollars.	17,100	17,000

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, provision of personnel and the U.S. share of cash for common project expenses at the ITER site, and the OPC funding for R&D and design activities supporting the TEC-funded procurements. This MIE is augmented by the technical output from a significant portion of the U.S. Fusion Energy Sciences community 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.

In FY 2007, the Total Project Cost remains unchanged from FY 2006, but the profile has changed and the funding requested in FY 2007 is lower than that shown in the FY 2006 President's Budget. The specific annual funding levels for TEC and OPC are subject to change when the performance baseline for scope, cost, and schedule of the U.S. MIE project is established (defined as Critical Decision 2 under DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets). There was significant progress in the Fall 2005 international negotiations, indicating the designation of the nominee Director General. The next steps include designation of the other key managers of the ITER project, completion of the ITER Agreement, governmental approval and signing of the Agreement, which for the United States requires a mandate from the U.S. Department of State, and Congressional approval, all of which leads to operation of a fully functioning ITER Organization working in concert with the Domestic Agencies (anticipated in the Summer 2007).

Accordingly, the estimated timeframe for establishing the U.S. performance baseline is the end of FY 2007.

FY 2005 Awards

FY 2005 awards or honors to and for researchers supported by FES include:

- Seven fusion scientists were made Fellows of the American Physical Society.
- A fusion materials scientist at ORNL has been named a UT-Battelle corporate fellow in recognition of his sustained and outstanding research contributions in the development of fusion materials.
- A fusion engineer at INL has been named a "Laboratory Fellow" because of his record of outstanding technical contributions, and recognition for his expertise both nationally and internationally in the fusion safety research area.
- A fusion scientist was named the DOE Office of Science Undergraduate Research Programs "Outstanding Mentor" of 2004.
- A graduate student working on a fusion experiment at the University of Wisconsin received the 2005 APS-DPP Marshall N. Rosenbluth Outstanding Doctoral Thesis Award in Plasma Physics.
- A fusion scientist received the Fusion Power Associates 2005 Leadership Award for his outstanding leadership of the DIII-D tokamak program at General Atomics.
- A fusion scientist at PPPL received the IEEE Particle Accelerator and Technology Award for 2005.
- A fusion scientist at the University of Texas at Austin received the 2004 State Scientific and Technological Cooperation Award of the People's Republic of China for contributing to Sino-U.S. cooperation in fusion.
- A fusion scientist at PPPL received the Chinese Institute of Engineers—USA Distinguished Achievement Award for outstanding leadership in fusion research and contributions to fundamentals of plasma science.
- A fusion scientist at Princeton University was awarded the American Physical Society's 2005 James Clerk Maxwell Prize for Plasma Physics for theoretical development of efficient radio-frequency-driven current in plasmas and for greatly expanding our ability to understand, analyze, and utilize wave plasma interactions.

- A fusion scientist at Lawrence Livermore National Laboratory and an another fusion scientist at General Atomics were jointly awarded the American Nuclear Society 2005 Edward Teller Prize for their contribution to the physics of inertial fusion.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all Office of Science 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 began new three-year 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 the sawtooth instability in tokamaks with realistic plasma parameters, and understanding turbulent transport as a function of plasma size in tokamaks. In early FY 2006, the Fusion Energy Sciences program and the Advanced Scientific Computing Research 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.

Scientific Facilities Utilization

The Fusion Energy Sciences 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 210 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 2005	FY 2006	FY 2007
Optimal hours[a]	2,800	2,800	2,800
Planned hours	1,936	1,168	1,440
Hours operated as percent of planned hours	108%	TBD	TBD

[a] This consists of 40 hours per week for DIII-D and NSTX and 32 hours per week for C-Mod.

In addition to the operation of the major fusion facilities, the NCSX MIE project at PPPL is supported in the fusion program. Milestones for this project are shown in the following table.

FY 2005	FY 2006	FY 2007
Award, through a competitive process, production contracts for the NCSX modular coil winding forms, conductor, and vacuum vessel. Complete winding of the first modular coil.	Complete fabrication of a vacuum vessel subassembly and two modular coils.	Complete winding of one half 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 2005, the FES program supported 430 graduate students and post-doctoral investigators. Of these, approximately 60 students conducted research at the DIII-D tokamak at General Atomics, the Alcator C-Mod tokamak at MIT, and the NSTX at PPPL. A Junior Faculty development program for university plasma physics researchers and the NSF/DOE partnership in basic plasma physics and engineering focus on the academic community and student education.

Data on the workforce for the FES program are shown in the table below.

	FY 2005	FY 2006 estimate	FY 2007 estimate
# University Grants	204	202	200
# Permanent PhD's (FTEs)[a]	692	685	678
# Postdoctoral Associates (FTEs)	103	102	101
# Graduate Students (FTEs)	327	324	320
# PhD's awarded	40	40	40

The Fusion Energy Sciences Advisory Committee conducted a study of the fusion workforce status and needs and published its findings in "Fusion in the Era of Burning Plasma Studies: Workforce Planning for 2004 to 2014," March 2004. FES recognizes the urgency in addressing the FESAC recommendations to meet future workforce needs, which requires tracking the number of current fusion researchers, encouraging new scientists in the field, especially from underrepresented groups, and developing opportunities for research. In response to the FESAC report, FES has increased the number of fusion fellowships for graduate students and postgraduate researchers, and faculty and students are encouraged

[a] Permanent PhD's includes faculty, research physicists at universities, and all PhD-level staff at national laboratories.

to conduct collaborative research on major fusion facilities. In FY 2005, an FES fellowship was awarded to an HBCU postdoctoral researcher to work at a DOE national laboratory. FES collects data on the retention of graduate students and postdoctoral fellows in fusion research, on the number of Plasma Physics Junior Faculty Development Program award recipients who have received tenure, and on staffing at all FES research institutions. FES encourages new institutions and researchers to the fusion program through the Plasma Physics Junior Faculty Development Program, the NSF/DOE Partnership, and the ICC program, and enhances the visibility of fusion researchers through programs in coordination with the APS-DPP and the Office of Science/Presidential Early Career Scientist and Engineer Award program.

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been 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.

Science

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Science			
Tokamak Experimental Research	47,052	46,517	45,838
Alternative Concept Experimental Research	59,484	60,550	56,302
Theory	25,749	24,928	23,900
SciDAC	4,033	4,222	6,970
General Plasma Science	12,176	13,760	13,941
SBIR/STTR	—	6,945	7,262
Total, Science	148,494	156,922	154,213

Description

The Science subprogram fosters 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 FES program in high energy density physics leverages and collaborates with NNSA's program efforts to pursue non-defense experiments on NNSA's facilities. The Science subprogram supports exploratory research to combine the favorable features of, and the knowledge gained from, magnetic confinement and/or inertial confinement, 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 and inertial confinement, 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.

Benefits

The Science subprogram provides the fundamental understanding of plasma science needed to address and resolve critical scientific issues related to fusion burning plasmas. 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 post docs, thus developing the national workforce needed to advance plasma and fusion science.

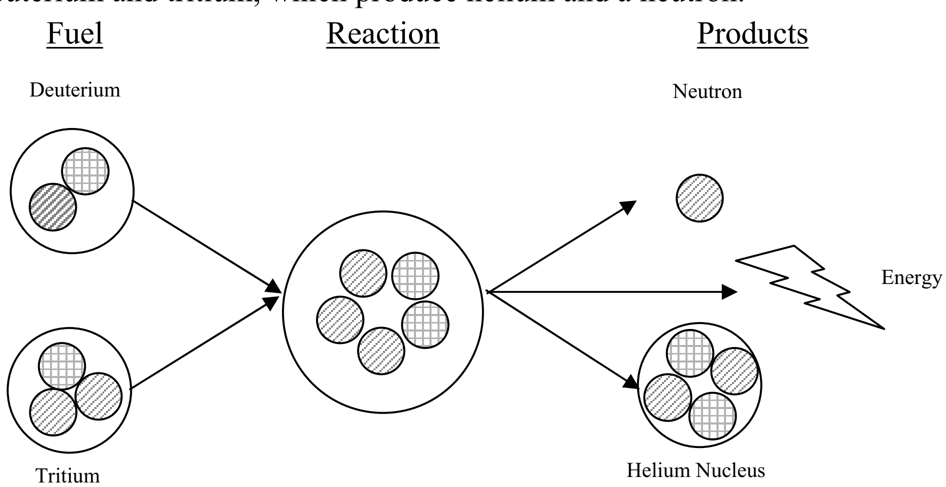
Supporting Information

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 Fusion Energy Sciences 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, an 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 Center 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 2005 Science Accomplishments

Progress on the international agreement to build ITER has energized fusion research around the world, enhancing international collaborations and encouraging closer collaborations between theory, simulation, and experiments. The number of experiments planned jointly by the International Tokamak Physics Activity (ITPA) on multiple facilities with different parameter regimes to investigate burning plasma and ITER related issues increased substantially in FY 2005. Greater effort is also focused on computer simulation tools to enhance predictive capability for advanced tokamaks and ITER.

Jointly funded by FES and Advanced Scientific Computing Research (ASCR), the National Fusion Collaboratory is continuing to develop and deploy collaborative software tools for use throughout magnetic fusion energy research. This effort includes creating a robust, user-friendly collaborative software environment (referred to as the National Fusion Grid) and deploying it to the more than 1,000 scientists in 40 institutions who perform magnetic fusion research in the United States and abroad. The main data repositories at the three major experimental facilities have been made securely accessible via Fusion Grid. Additionally, several fusion codes are now available on Fusion Grid including TRANSP, GATO—and GS2. One of these codes, "TRANSP"—a widely used system for simulation of fusion experiments—has performed over 2,000 simulations taking over 10,000 CPU hours for nine different experimental fusion devices. This collaborative technology is scalable to an international project like ITER.

Predictive Capability for Burning Plasmas

Experiments on the three major U.S. facilities (C-Mod, DIII-D, and NSTX) and coordinated experiments with international tokamaks under the ITPA/IEA Joint Experimental program have led to increased understanding of basic physics in the four major topical areas of fusion science (turbulence and transport, macroscopic equilibrium and stability, wave-plasma interactions and plasma heating, and edge/boundary layer plasma physics) and in critical physics issues for ITER. A key example of these issues is the development of plasma scenarios for both high performance operation to achieve high fusion gain (Q~10) in burning plasmas and for steady-state high performance operation to optimize future fusion power applications. Other important results include: elimination of edge localized modes (ELMs) through creation of resonant magnetic fields at the plasma edge in DIII-D using the internal control coils; plasma rotation studies and error field control in C-Mod and NSTX; stabilization of internal neo-classical tearing modes (NTMs) by driving plasma current in precise locations inside the plasma with electron cyclotron current drive; and measurement of energetic ions and a range of Toroidal Alfvén Waves created by them in DIII-D and NSTX. The planning and implementation of these and other similar experiments were made possible by extensive use of plasma control algorithms and active feedback stabilization assisted by high-speed computers.

Several major highlights from the experiments and advanced computing are discussed below.

- **Favorable Confinement Projection for ITER**

  Collaborative experiments between the United States and Europe on the DIII-D tokamak (at General Atomics) and the JET tokamak (UKAEA Culham Science Center) have obtained results that indicate ITER might perform better than its baseline design assumption. Until now, the standard projections of energy confinement for ITER have implied a strong degradation of energy confinement as the ratio of plasma pressure to magnetic pressure ("beta") was increased. In these experiments researchers could vary beta by a factor of 3 without penalty to energy confinement, thus implying that ITER could operate at a higher beta or plasma pressure and achieve either higher fusion power output and/or more ready access to steady-state operating modes in ITER. Confidence in this positive result was enhanced recently through a joint examination of confinement data from NSTX and MAST.

- **Plasma Flows and Plasma Rotation**

  It has long been known that plasma conditions near the edge of a tokamak can have profound impact on energy confinement deep within the plasma. Over the last year, experiments on C-Mod have revealed that plasma flowing along magnetic field lines that do not close on themselves allows coupling of momentum from the edge into the center of the plasma, which may be related to the up-down asymmetry in the power requirement for transition to high confinement. Using newly commissioned non-axisymmetric external field coils, an external control capability of plasma rotation was demonstrated on NSTX. The measured rotation damping profile from applied fields follows neoclassical toroidal viscosity theory.

- **Internal Transport Barriers**

  The plasma parameters of the internal transport barrier regime recently observed on C-Mod have been significantly extended, in which profiles spontaneously peak with off-axis radio-frequency heating. Using increased levels of both on- and off-axis power (4 MW total), both temperature and density profiles became highly peaked, leading to a greatly increased central pressure approaching four atmospheres. The plasma parameters of the ion internal transport barrier regime, regularly produced in High Confinement Mode plasmas on NSTX, have entered a new regime for many energy confinement times. This regime is characterized by high normalized plasma pressure, good confinement, and absence of significant MHD activities. This new regime suggests a new way to enhance the plasma performance for the ITER hybrid mode.

- **Plasma Microturbulence Code Achieves High Multi-Teraflop Performance**

  The Gyrokinetic Toroidal Code (GTC), the featured code in the SciDAC "Center for Gyrokinetic Particle Simulation for Turbulent Transport in Burning Plasmas" achieved an unprecedented 7.2 teraflop sustained performance using 4096 processors on the Earth Simulator Computer (ESC) in Japan. Since it used over 13 billion particles, the simulation was able to reach an extremely high statistical resolution which enabled systematic studies of key scientific questions, including the long-time temporal evolution of turbulence and the influence of nonlinear velocity-space dynamics in determining how quickly the plasma transport can reach saturation. The ability of the GTC code to scale so well and to effectively utilize greatly increased computational capability holds exciting promise for accelerating the pace to new scientific discoveries in this key area of fusion plasma research.

- **Nonlinear Simulations of Edge Localized Modes**

  The onset and nonlinear evolution of Edge Localized Modes (ELMs) were studied for the first time using two-fluid extended MHD models. ELMs are repetitive MHD oscillations occurring at the edge of magnetically confined plasmas and can affect global confinement and first wall performance. Both of the large nonlinear extended MHD codes being developed in the U.S.—NIMROD and M3D—produced remarkable simulations of the edge of the DIII-D tokamak undergoing an instability and, for the first time, provided us with an estimate of the heat flux to the surrounding wall due to the ELM activity. Understanding and controlling ELMs is very important for the operation of ITER because these instabilities can move large amounts of energy from the plasma core to the first wall and divertor plates of the device.

- **Active MHD Spectroscopy**

  Fusion power is proportional to the square of the plasma pressure. An upper limit to plasma pressure is set by the lowest order instability predicted by magnetohydrodynamic (MHD) theory. Referred to as the "kink mode," it leads to termination of the plasma discharge. Previously on DIII-D, it has been shown that this instability could be stabilized if the plasma is bounded by a nearby conducting wall and is rotating rapidly, allowing operation at up to twice the conventional pressure limit. NSTX has recently extended these results by reaching central plasma pressures up to 100% of the applied magnetic field pressure at the plasma major radius. Further information on MHD instabilities has been gained on DIII-D and NSTX by using a set of coils as an antenna (dubbed MHD spectroscopy) to apply a pulsed or rotating magnetic field with a large overlap in spatial structure with the basic unstable modes and finding the resonances. These measurements are now being compared to detailed code calculations that test various stabilizing mechanisms.

- **ITER level plasma pressure obtained in C-Mod**

  Using an all-metallic vacuum vessel wall coated with a thin layer of boron, Alcator C-Mod scientists have achieved a world record absolute pressure (about 6 atmospheres peak) for magnetic confinement experiments. Significantly, they achieved this result at the same value of plasma pressure relative to stability limits that is planned for the ITER baseline operation. This follows the removal of all low-Z materials from the C-Mod vessel at the end of FY 2004.

- **Simulation of Energetic Ion Driven Modes for Burning Plasma**

  The burning plasmas in ITER will be heated by "super-Alfvénic" energetic ions that move faster than the intrinsic "Alfvén" velocity of the magnetic plasma perturbations. NSTX, among major magnetic fusion facilities, is the only experiment designed to operate with such energetic ions under the normal conditions, where all parameters including the internal magnetic field can be measured. The Compressional Alfvén Eigenmodes (CAEs) and the Global Alfvén Eigenmodes (GAEs), previously predicted by theory, have been observed in a wide range of plasma conditions in NSTX. The presence of these modes is often (but not always) associated with a depleted distribution of the super-Alfvénic ions that interact strongly with such modes. Characterizing the interactions of these fast ions and the driven modes is important to establish a predictive understanding of their potential impact on the burning plasma performance in ITER.

- **DIII-D Control System for Fusion Plasma Discharges**

  Major progress has been made in feedback control of many plasma parameters using the highly-sophisticated DIII-D digital control system. This system involves representation of complex plasma physics issues in real time analysis of sensor data and determination of the required instructions to actuators to control the plasma parameters and their profiles. The system thus makes it possible to produce plasmas near their theoretical pressure limits for long pulses, mitigates disruptions, tests discharge scenarios against simulations, and sets up discharge scenarios very efficiently and effectively. The DIII-D control system is now being provided to several U.S. and international tokamaks (NSTX, KSTAR, EAST, and MAST) and it has high potential to be extrapolated to ITER.

- **Steady-State Plasmas for ITER**

  To operate ITER steady-state requires driving the plasma's electrical current (~10MA) by a combination of electromagnetic waves, particle beams, and the plasma's self-generated bootstrap current instead of using transformer coil induction. Plasma states were recently achieved in the DIII-D tokamak in which 100% of the plasma current was so obtained non-inductively, meeting or exceeding the parameters of ITER's projected steady-state operating scenario. At modest current where steady-state tokamaks are projected to operate, sufficient plasma pressure was obtained for an energy gain of 5 in ITER with 100% non-inductive operation and plasma confinement quality exceeding nominal expectations. On NSTX, a new rapid-response plasma control system improved the feedback control for vertical stability, enabling routine operation with plasmas of substantially stronger shaping (higher elongation and triangularity), improved stability, and increased bootstrap current, and leading to more stable plasmas with 50% longer pulse lengths in 2005 than achieved in previous years. Plasmas were developed with high elongations and triangularities, pulse lengths up to 50 times the plasma energy confinement times, and routine sustained plasma betas greater than 25%.

- **Edge Plasma Physics**

  Understanding edge plasma physics is important for tokamaks because the properties of the edge plasma affect both the flux of heat and particles to the material walls and the confinement of heat and particles in the core of the plasma. A very critical issue for ITER is the determination of the expected level of tritium retention by graphite plasma facing components (PFC), which are now commonly used in present tokamaks. The two approaches to this issue are the replacement of graphite PFCs with an all-metal wall and divertor system which does not retain tritium, or by developing techniques to easily remove tritium from graphite surfaces.

- **Measurements of Structure and Motion of Edge Turbulence**

  The 2-D structure of edge plasma turbulence in NSTX was measured by viewing the emission of deuterium or helium spectral lines locally enhanced by gas puffing with an ultra-high speed CCD camera. Transitions from low-confinement mode to high-confinement mode could appear as an evolution from a turbulent "blob-like" or intermittent state to a quiescent state over a period of 0.1 ms. However, no evidence was found, through the measured motion of the edge turbulence, to indicate a simultaneous occurrence of sheared plasma flow at the plasma edge during the confinement transition. Edge Localized Modes (ELMs) were observed to be closely associated with a sudden increase in the intermittent bursts of multiple "blobs." Understanding of these ELMs will contribute to avoiding large ELMs and their induced divertor erosion in ITER.

- **Predicting Tritium Co-deposition in ITER**

  In tokamaks with carbon first wall materials, the hydrogenic fuel species (tritium in ITER) is co-deposited on material surfaces with eroded carbon. Tritium thus trapped in ITER must be periodically removed. A first step toward such a removal scheme is to know where the tritium will be co-deposited. In the DIII-D tokamak, measurements and code simulations showed characteristic plasma flow patterns in the plasma boundary that implied deposits would form dominantly where the inner divertor leg contacted material surfaces. Carefully executed experiments using carbon-13 tracer elements that were injected into the plasma edge showed essentially all the carbon-13 was deposited where the inner divertor leg contacted material surfaces, confirming the result previously seen in the JET tokamak. These results suggest that in a divertor tokamak, the co-deposition area might be localized and predictable, the first step in being able to devise a tritium removal procedure.

Configuration Optimization

Since the inception of this program element in 1997, significant progress has been made in many confinement concepts. The highlights below cover the accomplishments in concepts other than Advanced Tokamaks in FY 2005.

- In the reversed field pinch experiment, the Madison Symmetric Torus (MST) at the University of Wisconsin in Madison, the plasma current has been increased to about 500 kilo-amps, resulting in an increase in the plasma temperature by 60% to near fusion-relevant levels of 16 million degrees Celsius.
- Coaxial Helicity Injection (CHI) has produced on NSTX the largest size and longest sustained spherical tokamak plasmas without use of an ohmic solenoid. The experiment utilized the transient CHI technique successfully tested earlier on the Helicity Injected Tokamak-II (HIT-II) of the University of Washington, extended the plasma volume and current generation efficiency by an order of magnitude, and doubled the plasma duration. This proves that the open magnetic field lines carrying the helicity-injected plasma current can reconnect and self-organize into toroidal plasmas of closed magnetic flux surfaces, indicating concrete progress toward enabling solenoid-free initiation and ramp-up of the plasma current in future Spheromak and spherical tokamak experiments.
- Magnetic helicity is nature's way of "trapping" magnetic flux and electrical currents in some self-organized manner that allows magnetic and plasma energy to be transported in space and time. When magnetic helicity is captured in a toroidal form in a simple vacuum vessel instead of a toroidal chamber, the configuration is a spheromak. The spheromak has the potential of a magnetic toroidal confinement system without the inconvenience (and cost) of the center stack of a tokamak. Because magnetic helicity decays due to dissipative processes, a fundamental issue in spheromak research is its sustainment. To that end, short pulses of magnetic helicity were injected into the Sustained Spheromak Physics Experiment (SSPX) at the LLNL and were successfully retained by the spheromak. Concurrently, better pulse-shaping through computational modeling has enabled the quality of energy confinement in the plasma to be improved by nearly an order of magnitude, leading to a dramatic increase in the plasma temperature from 2.5 million degrees to over 4 million degrees Celsius, the highest temperature ever achieved in a spheromak with helicity injection.
- The actual self-organization of the magnetic flux and electrical currents to create magnetic helicity to form a spheromak involves reconnection of magnetic field lines, a phenomenon of a high degree of physical complexity. The complex sequence of events was captured experimentally for the first time in a small university-scale experiment at the California Institute of Technology. The merging of eight plasma-filled magnetic flux and current tubes were observed to form a plasma jet which undergoes kink instability leading to magnetic reconnection and helicity creation and eventually the formation of a spheromak.
- One method of heating plasma consists of compressing magnetized plasma by an imploding material wall. This involves imploding a hollow cylindrical metallic shell by passing a large electrical current (about 10 megamperes) through it between two planar electrodes. Since there must be a hole in at

least one of the electrodes in order to insert magnetized plasma into the hollow shell, the body of the cylindrical shell must be imploded while the ends of the shell are sufficiently constrained that they do not slide into the holes in the electrodes. In the past year, aluminum shells (containing no plasma), were successfully imploded, achieving a radial convergence ratio of about 17 to 1. Good electrical contact was maintained between the shell and the electrodes throughout the implosion. The experiment is now poised to compress a magnetized plasma to temperatures potentially in excess of 10 million degrees Celsius.

- A configuration in which a plasma torus with a predominantly toroidal current is contained within a solenoidal magnetic field is called a Field Reversed Configuration (FRC). The ratio of the plasma thermal pressure to the magnetic field energy density, called beta, is a measure of the efficiency at which the magnetic configuration is used to confine the plasma (a high value of plasma beta is an attractive feature of a confinement configuration). An FRC has a plasma beta close to unity, which is among the highest of all magnetic confinement configurations. High densities will further enhance the attractiveness of an FRC. In the FRX-L experiment at the Los Alamos National Laboratory, an FRC with a density of 4×10^{16} ions per cm^3, the highest density achieved in a compact FRC with a temperature exceeding about 4 million degrees Celsius, has been created in the past year. While FRCs have reached this plasma density previously, they were much larger in size. This class of FRCs is suitable for compressional heating studies of magnetized plasma.
- A confinement configuration being investigated consists of a levitated magnetic dipole, an experiment in progress at MIT in collaboration with Columbia University. The configuration is inspired by nature’s way of confining plasma in planetary magnetospheres. After several years of development, the experiment is now operational. Results include (1) record levels of diamagnetic flux exclusion that indicate high plasma pressure, (2) clear indications of a relationship between power deposition and pressure profile, and (3) improved time response measurements of x-ray emission showing the effects of magnetohydrodynamic activity at pressure limits.

High Energy Density Physics

- In heavy ion beam research, the most significant challenge in the near term is developing techniques for the compression of the beam to achieve ion beams of extremely high intensity, and exploring the physics limits of the compression. In the past year, compression of the ion beams with an intensity multiplication of 50 times has been demonstrated with a new technique of compressing the beam longitudinally in a neutralizing plasma, by chirping the beam so that the tail of the beam is accelerated and the head of the beam is decelerated. As the beam drifts in the neutralizing plasma, the beam compresses itself longitudinally.
- In fast ignition, the most critical issue at present is unraveling the physics of the propagation of relativistic electron jets produced by a petawatt laser in a dense plasma. In the past year, experiments have revealed for the first time the spread in the trajectories of the electron jets in a dense plasma of solid density and its correlation to the effects of the electrical resistivity of the cold dense plasma.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Tokamak Experimental Research	**47,052**	**46,517**	**45,838**

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 the Massachusetts Institute of Technology. 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.

U.S. tokamak research, including experiments on the DIII-D and C-Mod tokamaks in the U.S. and collaborations on the new and operating international tokamaks, will expand the effort in support of burning plasmas and ITER. DIII-D will have the opportunity to further exploit new experimental flexibilities acquired through hardware improvements in FY 2005 and FY 2006. C-Mod will pursue a program with high power densities approaching those of ITER while contributing to answering ITER-relevant questions. 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 and disruption mitigation, control of intermittent edge plasma instabilities (ELMs) through manipulation of magnetic flux at the plasma edge, 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.

▪ **DIII-D Research**	**24,042**	**24,412**	**24,300**

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

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

divertor" to control the magnetic field configuration at the edge of the plasma. The divertor is produced by magnet coils that bend the magnetic field at the edge of the tokamak out into a region where plasma particles following the field are neutralized and pumped away.

The DIII-D experimental program contributes to all four key Magnetic Fusion Energy (MFE) fusion topical science areas of energy transport, stability, plasma-wave interactions, and boundary physics, and to various thrust areas that integrate across topical areas to support the goal of achieving burning plasma. In the past three years, the investigation of ITER relevant discharge scenarios has gained emphasis in the DIII-D experimental program. The DIII-D experimental flexibility is being greatly increased by hardware improvements in FY 2005 and FY 2006. These include acquisition of three long pulse (10 seconds) 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, and improvements to the cooling tower and bus bars in order for high performance plasmas to be operated for long pulses.

In FY 2007, the DIII-D program will aggressively exploit the new experimental flexibility acquired in FY 2005 and FY 2006. With an operating time of 12 weeks, a five week increase over FY 2006, the DIII-D program will be able to accommodate a larger number of ITPA joint experiments with the international community. The DIII-D experiments will emphasize support of burning plasmas and ITER physics, in addition to exploring the basic physics issues in energy transport, plasma stability, and wave particle interactions which help grow the field of plasma physics and its relationship to other fields of science such as astrophysics. These experiments will enhance the understanding of energy and particle transport, the role of plasma rotation and its impact on plasma transport and stability, and prepare the U.S. fusion community to better exploit burning plasma physics studies on ITER.

	FY 2005	FY 2006	FY 2007
▪ **Alcator C-Mod Research**	**8,636**	**8,510**	**8,890**

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 unique in the use of metal (molybdenum) walls to accommodate high power densities.

By virtue of these characteristics, Alcator C-Mod is particularly well suited to operate in plasma regimes that are relevant to ITER, as well as to compact, high field, high density burning plasma physics tokamaks. Burning plasmas can be achieved for short pulses in a low cost tokamak by trading high magnetic field for large size (and cost). Alcator C-Mod has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks; these are important integrating issues related to ignition and burning of fusion plasma.

In FY 2007, C-Mod will conduct an aggressive research program with studies and comparisons of high-Z vs. low-Z first walls and performance of the tungsten divertor module under ITER-like high power density. The physics of RF wave synergies will be studied in cases showing promise for efficient current drive. ITER hybrid scenarios will be examined under ITER-relevant ion/electron temperature equilibrated conditions. ITER quasi-steady-state operating scenarios using Lower

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

Hybrid microwaves and radio frequency waves will be developed. Strong plasma rotation in the absence of direct torque application, also very important to ITER stability, will be explored.

Compact, high field tokamak regimes and operating scenarios required for ignition in compact devices will be further explored. Resources will be increasingly focused on ITER-relevant topics such as understanding the physics of the plasma edge in the presence of large heat flows, measuring the effects of and mitigating disruptions in the plasma, controlling the current density profile for better stability, non-inductively driving a large part of the plasma current and helping build cross-machine data bases using dimensionless parameter techniques.

Research will also continue to examine the physics of the operational density limit, power, and particle exhaust from the plasma, mechanisms of self-generation of plasma flows, and the characteristics of the operating modes achieved when currents are driven by electromagnetic waves. It will also focus on studying transport in the plasma edge at high densities and in relation to the plasma density limit. The new diagnostic neutral beam will further improve visualization of turbulence in the edge and core of high density plasmas, and new diagnostics will shed light on the physics of temperature and density profiles, whose features are now thought to be the key to predicting tokamak behavior.

	FY 2005	FY 2006	FY 2007
▪ **International**..	**5,116**	**4,826**	**5,064**

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad, and conduct comparative studies to enhance understanding of underlying physics. The Fusion Energy Sciences program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. 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-60 in Japan), a stellarator (the Large Helical Device) in Japan, a superconducting tokamak (Tore Supra) in France, and several smaller devices. In addition, the U.S. is collaborating with South Korea and China on the design of plasma diagnostics, control systems, and preparations for physics operations on the new long-pulse, superconducting, advanced tokamaks, KSTAR and EAST, respectively. These collaborations provide a valuable link with the 80% of the world's fusion research that is supported and conducted outside the United States.

The increase from the FY 2006 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 in the EU and Japan, respectively, some joint experiments on medium sized tokamaks such as TEXTOR and ASDEX-UG in the EU, 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 in the EU, KSTAR in Korea, and EAST in China will be maintained. These activities will prepare U.S. scientists for participation in burning plasma experiments on ITER.

	FY 2005	FY 2006	FY 2007
▪ **Diagnostics**	**3,894**	**3,763**	**3,854**

Support of the development of unique measurement capabilities (diagnostic instruments) that provide an understanding of the plasma behavior in fusion research devices will continue. The development of new diagnostics is needed to obtain data on current experiments such as DIII-D in

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

the United States and JET in Europe (through collaborative programs) in order to investigate their applicability to ITER. Among the key areas of diagnostic research are the development of: (1) techniques to measure the loss of energy/heat and particles from the core of magnetically confined plasmas, including techniques aimed at understanding how barriers to energy/heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; and (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which add unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2007 supports research that will enhance our understanding of critical plasma phenomena and the means of affecting these phenomena to improve energy and particle confinement in tokamaks and innovative confinement machines.

	FY 2005	FY 2006	FY 2007
▪ **Other**	**5,364**	**5,006**	**3,730**

Funding for educational activities in FY 2007 will support research at historically black colleges and universities (HBCUs), graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, and outreach efforts related to fusion science and enabling R&D. Funding is reduced in order to support higher priority activities within the program.

	FY 2005	FY 2006	FY 2007
Alternative Concept Experimental Research	**59,484**	**60,550**	**56,302**

The properties of a magnetically confined plasma depend on the structure of the confining magnetic field. For example, the structure of the confining magnetic field can affect the upper limit of the plasma pressure. Since fusion energy production increases with the square of the plasma pressure, understanding the cause of the pressure limit and optimizing the confinement configuration to achieve high pressure are important issues for fusion scientists. Thus, a significant amount of research is focused on alternative confinement approaches, aimed at extending fusion science and identifying innovative confinement concepts that could improve the economic and environmental attractiveness of fusion, thereby lowering the overall programmatic risk and cost of the Fusion Energy Sciences program in the long term. The largest element of the alternative concepts program is the NSTX at Princeton Plasma Physics Laboratory that began operating in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national collaborative scientific facility. The Madison Symmetric Torus (MST) is at an intermediate stage of development between a small-scale experiment and a major facility.

	FY 2005	FY 2006	FY 2007
▪ **National Spherical Torus Experiment (NSTX) Research**	**15,992**	**15,845**	**16,696**

NSTX and the MAST device in the U.K. are the world’s two largest spherical torus confinement experiments. Spherical toruses 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. Plasmas in a spherical torus are predicted to 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, 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 2007, 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 emphasize short wavelength turbulence and electron transport. Macroscopic stability studies will concentrate on the use of feedback stabilization and strong shaping to control pressure-limiting modes. Specific experimental campaigns will focus on 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. Wave-particle research will contribute to the understanding of fast-ion driven modes, which will be important for ITER. Boundary physics studies will focus on understanding transport barriers and intermittent transport of heat and particles in the plasma edge. Finally, integrated scenario investigations will center on non-inductive current ramp-up and sustainment of high performance plasmas.

	FY 2005	FY 2006	FY 2007
▪ **Experimental Plasma Research**	**21,656**	**21,778**	**19,990**

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 25 experiments and theory-support projects, involving 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 post-docs, 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 energy sciences.

Current projects in this program element include fundamental investigations into concepts such as, advanced stellarator configurations, tokamak innovations, the levitated dipole, field-reversed configurations (FRC), spheromaks, and magnetized target fusion.

In FY 2007, funding is reduced by $1,788,000 to meet higher priority needs of the program which will lead to a reduction of all the projects in this area.

Examples of the research being pursued in this element includes:

- Complementing the advanced tokamak research on DIII-D and Alcator C-Mod is the exploratory work on the High Beta tokamak (HBT) at Columbia University. This small tokamak's goal is to demonstrate the feasibility of stabilizing instabilities in high pressure tokamak plasmas using a combination of a close-fitting conducting wall and active feedback. This work is closely coordinated with the DIII-D program, and promising results have already been achieved on DIII-D.

- Research in advanced stellarators, such as the Helically Symmetric Experiment (HSX) at the University of Wisconsin explores the symmetry characteristics that make quasisymmetrical stellarators different from all other toroidal confinement systems. HSX is studying transport attributable to fluctuations, and exploring stability and beta limits. Such studies will be applicable to the NCSX, a proof of principle experiment currently under fabrication.
- Field-reversed configurations and spheromaks are toroidal plasma confinement configurations like the tokamak but without the need of a center pole, making them candidates for highly compact fusion reactors. In field-reversed configurations (FRC), current research is exploring an avenue to form and sustain the FRC using a rotating magnetic field (RMF).
- Spheromaks are plasmas with self-organized internal plasma currents which generate magnetic fields that confine the plasma, eliminating the need for the toroidal magnets and ohmic heating transformer which necessarily thread the vacuum vessel in the tokamak. Current research aims at generating, amplifying and sustaining these internal plasma currents (related to its magnetic helicity) by the use of coaxial plasma guns (known as coaxial helicity injection).
- Research in magnetized target fusion aims at combining the favorable features of both magnetic and inertial confinement, without using the expensive magnets of conventional magnetic fusion, while using drivers that are much less expensive than those necessary for conventional Inertial Fusion Energy research. This project is poised to produce a high-density, magnetized plasma to be imploded by a deformable liner to achieve temperatures over 10,000,000 degrees Celsius in FY 2007 and densities above 1,018 ions per cm^3.
- The Levitated Dipole Experiment (LDX) explores plasma confinement in a novel magnetic dipole configuration similar to the magnetic field that confines the plasma in the earth's magnetosphere.

	FY 2005	FY 2006	FY 2007
▪ **High Energy Density Physics**	**14,640**	**15,856**	**11,949**

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), which cuts across several fields of contemporary physics including astrophysics. 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.

In FY 2007, $3,762,000 is requested to sustain research in Fast Ignition and high Mach number plasma jets. Both Fast Ignition and dense plasma jets are exciting new fields of HEDP that are attracting worldwide scientific attention. This is evidenced by the numerous papers on these two subjects at the recent 2005 American Physical Society Division of Plasma Physics meeting. The relativistic physics of thermal transport in Fast Ignition is being explored. Modest efforts to explore experimental techniques to produce high Mach number, high density plasma jets in the laboratory, and study their application to HEDP are being pursued. This research follows the recommendations of the OSTP National Task Force on High Energy Density Physics (July 2004) and two NRC reports, entitled "Frontiers in High Energy Density Physics" and "Connecting Quarks to the Cosmos." The research leverages and collaborates with NNSA's program efforts in non-defense areas of high energy density physics and makes use of NNSA's facilities. Collaboration will be extended to other Federal agencies as well, wherever appropriate, through an interagency process that is in progress.

In FY 2007, $8,187,000 is requested to continue research in heavy ion beam science. Non-defense research at the Atlas pulsed power facility will be discontinued.

	FY 2005	FY 2006	FY 2007
▪ **Madison Symmetrical Torus (MST)**	**6,423**	**6,320**	**6,970**

The goal of the MST experiment is to obtain a fundamental understanding of the physics of reversed field pinches (RFP), particularly magnetic fluctuations and their macroscopic consequences, and to use this understanding to develop the RFP fusion configuration. 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 RFP are being investigated in the MST experiment. Magnetic fluctuations and its macroscopic consequences including transport, dynamo, stochasticity, ion heating, magnetic reconnection, and momentum transport, have applications across a wide spectrum of fusion science and astrophysics, to which the MST experiment thus contributes. MST is one of the four leading experiments in RFP research in the world, and is unique in that it pioneered the reduction of magnetic fluctuations by current density profile control. This approach has led to a ten-fold increase in energy confinement. Continual developments in the experimental facility and the theory build-up in the last few years will enable productive studies in FY 2006 of one or more of the following techniques as mechanisms for driving and controlling the current profile, as well as for heating and fueling the plasma: inductive electric field programming, electromagnetic waves, oscillating field helicity injection, neutral beams, and pellet injection. With potentially improved plasmas in MST obtained with one or more of the most highly developed of these techniques, separately or in combination, the major experimental undertaking in FY 2007 will be to continue the measurement and modeling of improved confinement and sustainment in MST with greatly reduced dynamo activity initiated in FY 2006.

	FY 2005	FY 2006	FY 2007
▪ **National Compact Stellarator Experiment (NCSX) Research**..	**773**	**751**	**697**

This funding supports the research portion of the program to be executed with the NCSX Experiment 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 keeps abreast of physics developments in domestic and international stellarator research, factoring those developments into the 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) adapt analytical tools to establish requirements and physics designs for magnetic diagnostic upgrades, (2) prepare for experiments to elucidate key configuration characteristics by e-beam mapping, including the study of effects of field perturbations

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

such as coil leads and feeds, and fabrication errors, and (3) adapt and apply analytical tools and incorporate experimental results from foreign stellarator divertor experiments to develop design requirements for plasma-facing components.

	FY 2005	FY 2006	FY 2007
Theory	**25,749**	**24,928**	**23,900**

The theory and modeling program provides the conceptual underpinning for the fusion sciences program. Theory efforts meet the challenge of describing complex non-linear plasma systems at the most fundamental level. These descriptions range from analytic theory to highly sophisticated computer simulation codes, both of which are used to analyze data from current experiments, guide future experiments, design future experimental facilities, and assess projections of their performance. Analytic theory and computer codes represent a growing knowledge base that, in the end, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and controlled.

The theory and modeling program is a broad-based program with researchers located at five national laboratories, over 30 universities, and three private companies. Institutional diversity is a strength of the program, since theorists at different types of institutions play different roles in the program. Theorists in larger groups, that are mainly at national laboratories and industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring multidisciplinary teams. Those at universities generally support smaller, innovative experiments or work on more fundamental problems in plasma physics.

The theory program is composed of two elements—tokamak theory and alternate concept theory. The main thrust of the work in tokamak theory is aimed at developing a predictive understanding of advanced tokamak operating modes and burning plasmas, both of which are important to ITER. These tools are also being extended to innovative or alternate confinement geometries. In alternate concept theory, the emphasis is on understanding the fundamental processes determining equilibrium, stability, and confinement in each concept.

	FY 2005	FY 2006	FY 2007
SciDAC	**4,033**	**4,222**	**6,970**

An important element of the Office of Science's Scientific Discovery through Advanced Computing (SciDAC) program is the FES-funded portion. 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 the fusion simulation project. The 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 as part of the Fusion Simulation Project, 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 2007, 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

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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. In addition, two additional SciDAC projects will be competitively selected. One project will focus on developing the software tools for remote collaboration on foreign fusion facilities, and the other will focus on developing a framework for integrated simulations of fusion plasma systems.

General Plasma Science	**12,176**	**13,760**	**13,941**

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 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 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. The Department is spending approximately $2,390,000 on the Fusion Science Center program each year in FY 2005 and FY 2006. 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. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. The FES program will continue to share the cost of funding the multi-institutional plasma physics frontier science center funded by NSF starting in FY 2003.

SBIR/STTR	**—**	**6,945**	**7,262**

In FY 2005, $6,211,000 and $745,000 was transferred to the Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2006 and FY 2007 amounts are the estimated requirements for the continuation of these programs.

Total, Science	**148,494**	**156,922**	**154,213**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Tokamak Experimental Research	
▪ **DIII-D Research** The decrease will reduce the research effort on the optimization of tearing mode stabilization and the exploration of the ultimate stability limits of high triangularity double-null plasmas.	-112
▪ **Alcator C-Mod Research** The increase will fund initial demonstration of radio-frequency driven current profile control while continuing to conduct other collaborative experiments of strong relevance to ITER.	+380
▪ **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 EU and Japan, and to participate in the new superconducting tokamaks in Korea and China.	+238
▪ **Diagnostics** The increase will maintain the level of effort for developing new base-program and ITER-relevant diagnostics.	+91
▪ **Other** The decrease will reduce support for education and HBCU programs due to the support needed for the other priority activities of the program.	-1,276
Total, Tokamak Experimental Research	**-679**
Alternate Concept Experimental Research	
▪ **National Spherical Torus Experiment (NSTX) Research** The increase will maintain the NSTX research team at current staffing levels and cover increased travel costs for collaborators.	+851
▪ **Experimental Plasma Research** The decrease will reduce research grants to universities and national laboratories for individual researchers by 8% in this program	-1,788
▪ **High Energy Density Physics** Research in Fast Ignition and high Mach number plasma jets will be reduced by $1,779,000, curtailing U.S. participation in Japan's FIREX-1 experiment, eliminating experiments at the OMEGA facility, especially experiments involving cryogenic targets, reducing development of computational capabilities for Fast Ignition and plasma jets, and eliminating investigations of magnetized	

	FY 2007 vs. FY 2006 ($000)
high energy density physics. Diagnostics development on the High Current Experiment for ion beams will be reduced by $1,138,000. Non-defense research at the ATLAS pulsed power facility in Nevada, which was funded by Congressional direction in FY 2006 at $990,000, will not be continued.	-3,907
▪ **Madison Symmetric Torus (MST)**	
The increase will allow the completion of the programmable power supply required for current profile control.	+650
▪ **National Compact Stellarator Experiment (NCSX) Research**	
The decrease will slightly reduce efforts on diagnostic upgrades for future NCSX experiments.	-54
Total, Alternative Concept Experimental Research	**-4,248**
Theory	
Funding for Theory is decreased to support higher priority activities. It will result in the termination of three to four university theory programs and their associated academic and research faculty. It will also result in the loss of up to eight graduate students and four postdoctoral fellows, and the loss of two research scientists from theory programs at national laboratories.	-1,028
SciDAC	
The increase will permit the initiation of two additional SciDAC projects, an integrated simulation development center, and a remote collaboration tool development project.	+2,748
General Plasma Science	
The increase will be used to support high-quality grants funded under the NSF/DOE Partnership in Basic Plasma Science and Engineering.	+181
SBIR/STTR	
Support for SBIR/STTR is provided at the mandated level.	+317
Total Funding Change, Science	**-2,709**

Facility Operations

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Facility Operations			
DIII-D	31,709	30,280	32,362
Alcator C-Mod	13,402	13,207	13,941
NSTX	18,495	18,140	18,422
NCSX	17,500	17,019	15,900
GPP/GPE/Other	3,176	3,189	3,930
ITER Preparations	5,451	5,835	—
U.S. Contributions to ITER (MIE TEC)	—	15,866	37,000
Total, Facility Operations	89,733	103,536	121,555

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 newer 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 National Compact Stellarator Experiment (NCSX) MIE project at PPPL. In FY 2007, the project will be in its fifth year; PPPL will continue with the fabrication of the device with the focus being on winding the modular coils and assembling the vacuum vessel.

The FY 2007 request provides for the second year of funding for the U.S. Contributions to ITER MIE project. The FY 2007 Total Estimated Costs (TEC) funding of $37,000,000 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, and cash for common needs such as infrastructure, hardware assembly, and installation of ITER components. The funding cap of $1,122,000,000 is maintained. However, the profile shows a more modest first two years than was contained in the FY 2006 President's Budget. The MIE project is being managed by the U.S. ITER Project Office in accordance with DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets. There is a necessary shift indicated in the FY 2007 TEC and OPC categories to accommodate domestic and international project priorities under the revised funding profile. The OPC funding, in the Enabling R&D subprogram, includes R&D and design tasks in support of the procurements for the U.S. Contributions to ITER

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 fourth year of a five year effort to support the move of ORNL fusion personnel and facilities to a new location at ORNL.

FY 2005 Facility Operations Accomplishments

In FY 2005, 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:

- GA initiated hardware improvements, including the rotation of a beam line for investigation of the role of plasma rotation on transport, installation of particle pumping in the lower divertor for effective use of the double-null configuration in DIII-D, and acquisition of three long pulse (10 second) gyrotrons for high power current drive and plasma control. Experimental operations totaling 15.6 weeks were achieved, in excess of the planned 14 weeks.
- PPPL NCSX placed orders for both the 18 modular coil winding forms (MCWFs) and vacuum vessel sectors in early FY 2005. The MCWFs are steel structures that support the modular coil windings and locate them to high accuracy. The vacuum vessel is a highly shaped structure with stringent requirements on vacuum quality and magnetic permeability. Fabrication of the MCWFs and vacuum vessel segments was initiated in FY 2005, and winding of the first MCWF is scheduled in FY 2006.
- The plasma control system for NSTX was upgraded to achieve approximately 1 millisecond response times. This faster control system, combined with the use of the real-time equilibrium fitting routine developed by GA, permits precise control of the plasma shape, enabling the achievement of higher elongation and triangularity.
- In FY 2005, installation of a new diagnostic neutral beam was completed on Alcator C-Mod. The new beam is expected to enhance performance of the many diagnostic systems it supports. C-Mod's

new lower hybrid radio frequency antenna system, which is predicted to have high plasma current drive efficiency, has also been installed. The results from experiments conducted with this antenna will help determine if such a system should be included in ITER. In addition, C-Mod set a new world record in volume-averaged tokamak plasma pressure of 1.8 atmospheres. Experimental operations totaling 18.4 weeks were achieved, in excess of the planned 17 weeks.

The table and chart below summarize the recent and longer-term history of operation of the major fusion facilities.

Weeks of Fusion Facility Operation

	(weeks of operations)		
	FY 2005 Results	FY 2006 Target	FY 2007 Target
DIII-D	15.6	7	12
Alcator C-Mod	18.4	14	15
NSTX	17.9	11	12
Total	51.9	32	39

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
DIII-D	**31,709**	**30,280**	**32,362**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. In FY 2007, these funds support 12 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram. These funds also provide for beginning phased upgrading of the facility power infrastructure to support maximum utilization of the auxiliary heating systems that were improved in FY 2005 and FY 2006.

Alcator C-Mod	**13,402**	**13,207**	**13,941**

Support is provided for operation, maintenance, minor upgrades, and improvement of the Alcator C-Mod facility and its auxiliary systems, such as an advanced divertor module, a toroidal phase contrast imaging system, and a laser-induced fluorescence diagnostic for edge fluctuation mapping. In FY 2007, there is funding for 15 weeks of operation and a few minor facility upgrades that will enable additional ITER-relevant experiments in the future.

National Spherical Torus Experiment (NSTX)	**18,495**	**18,140**	**18,422**

Support is provided for operation, maintenance and minor upgrades, such as an interim poloidal charge exchange recombination spectroscopy system, a fast IR camera, divertor diagnostics, and preparation for next-step fluctuation diagnostics. In FY 2007, 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 (NCSX)	**17,500**	**17,019**	**15,900**

Funding is requested in FY 2007 for the continuation of the NCSX Major Item of Equipment, which was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

principle class experiment. These funds will allow for the continuation of procurement of major items and fabrication of the 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. The new cost and schedule performance baseline, developed to be consistent with the FY 2006 budget request and approved in July 2005, increases the TEC of NCSX to $92,401,000, with completion in July 2009.

	FY 2005	FY 2006	FY 2007
General Plant Projects (GPP)/ General Purpose Equipment (GPE)/Other	**3,176**	**3,189**	**3,930**

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 continuing move of ORNL fusion facilities to a new location at ORNL.

	FY 2005	FY 2006	FY 2007
ITER Preparations	**5,451**	**5,835**	**—**

Preparations funding for ITER ends in FY 2006 as the U.S. Contributions to ITER MIE begins. Funding was provided to continue the ITER transitional activities such as safety, licensing, project management, preparation of specifications and system integration. U.S. personnel are participating in these activities in preparation for U.S. participation in the international ITER Project. Discussions are proceeding on whether these costs should be accounted for within the ITER TPC. A determination will be part of the Critical Decision–1 process.

	FY 2005	FY 2006	FY 2007
U.S. Contributions to ITER - (MIE TEC)	**—**	**15,866**	**37,000**

The U.S. Contributions to ITER MIE project provides hardware, personnel, and cash to the international ITER Project. Following the ITER site selection decision of Cadarache, France, in June 2005, the United States began negotiating the remaining details of the ITER Agreement with the other ITER parties of the European Union (EU), Japan, the Russian Federation, China, and South Korea, with completion of the Agreement anticipated by early 2006. During these negotiations, ending in December 2005, the text of the draft ITER Agreement and supporting documents were completed, the designation of the Director General Nominee was approved, and India joined the negotiations as a full non-host ITER participant. The U.S. Contributions to ITER MIE project supports the fabrication phase of the international Project; however, the international negotiations and the ITER Agreement will involve all phases of the ITER Program including construction, operation, deactivation and decommissioning. For each of the ITER program phases, the United States is negotiating financial participation at the non-host level. After the ITER Agreement is completed and accepted by the negotiators, then signed by the parties' governments and entered into force, an ITER legal entity will exist. The ITER Organization, being staffed from personnel from all the ITER parties, is responsible for the realization of the ITER facility and program. The personnel, a mix of secondees from organizations within the ITER parties' countries and employees of the ITER Organization, is mobilizing to the Cadarache site.

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 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 during 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 will be consistent with the standard DOE process in support of long-lead procurement for the manufacture of the components.

DOE’s involvement with ITER at the international site will be at the level of approximately 9.1 percent, which is consistent with the other non-host participants. In addition to scientists and engineers assigned to the ITER Organization, the United States expects to provide at least one senior management staff member to the ITER Organization. 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 long lead hardware, U.S. personnel assigned to the project abroad (the annual average number of engineers and scientists is ~22 FTEs as well as funding for support personnel at the international ITER site for ~34 FTEs), 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 follow 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 Program and, as appropriate, internationally. For direct procurements with industry, the Project Office is expected to assemble experts throughout the fusion program for technical follow-up and execution of the procurements. Such experts, and their institutions, would become members of the U.S. ITER Project Office team although not necessarily located at Princeton or Oak Ridge.

Given the significant advances during the international ITER negotiations, it is the objective of the international ITER parties to obtain the negotiators' acceptance of the ITER Agreement by early 2006 indicating the end of the negotiations. The next step will be to obtain governmental signatures on the completed ITER Agreement later in FY 2006, by all ITER parties, thereby leading to a multilateral commitment for ITER. The Agreement finalizes the allocation of equipment to be provided by each ITER Party, including India, and finalizes the concepts for mode of operation among the ITER Parties and central project team during the construction, operation, and decommissioning phases of the ITER program.

The final allocation of equipment or hardware to be supplied by the United States, also called "in-kind" contributions to ITER, is indicated below.

- Niobium Tin (Nb3Sn) Superconducting Strand – Niobium, tin and copper filaments formed into long strands.
- Superconducting Cable – multi-stage cable including strand and insulation.
- Central Solenoid Coil – 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.

(dollars in thousands)		
FY 2005	FY 2006	FY 2007

- Cooling Water System – the ITER tokamak water cooling systems 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.

The preliminary schedule and TEC funding profile for the U.S. Contributions to ITER MIE are as follows. 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. However, the overall TPC for this MIE project will not change with the exception of possible changes from the OMB-inflation rates that are in place at the time that the performance baseline is set, and changes in currency exchange rates affecting about 15% of the TPC funding.

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 Costs ($000)
FY 2006 Budget Request (Preliminary Estimate)	3Q FY 2006	4Q FY 2012	2Q FY 2006	4Q FY 2013	1,038,000
FY 2007 Budget Request (Preliminary Estimate)	4Q FY 2006	4Q FY 2012	2Q FY 2006	FY 2014	1,077,051[a]

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. In addition, shifts between OPC and TEC funding have been made consistent with the intentions of DOE 413.3 to provide for R&D and design in support of the MIE project. During FY 2006, several U.S. reviews are scheduled to validate the preliminary cost and schedule profile for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2006 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-2 planned for September 2007.

Financial Schedule

Total Estimated Cost (TEC)[a]

(budget authority in thousands)

Fiscal Year	MIE TEC[b]
2006	15,866
2007	37,000
2008	149,500
2009	208,500
2010	208,500
2011	180,785
2012	130,000
2013	116,900
2014	30,000
Total	1,077,051

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
Total, Facility Operations	**89,733**	**103,536**	**121,555**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
DIII-D	
DIII-D will increase experimental operations to 12 weeks, a five week increase over FY 2006. Power systems infrastructure will begin to be upgraded to support the full capabilities of the auxiliary heating systems that were improved in FY 2005 and FY 2006	+2,082
Alcator C-Mod	
The increase will allow C-Mod to continue ITER-relevant experiments, such as studies in high-Z vs. low-Z wall materials and lower hybrid radio frequency injection, while making important upgrades to its divertor module and diagnostics for use in future advanced tokamak experiments. The increase will also allow C-Mod to conduct 15 weeks of operation, an increase of one week over FY 2006.	+734

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[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. In addition, shifts between OPC and TEC funding have been made consistent with the intentions of DOE 413.3 to provide for R&D and design in support of the MIE project. During FY 2006, several U.S. reviews are scheduled to validate the preliminary cost and schedule profile for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2006 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-2 planned for September 2007.

[b] Note that the Other Project Costs associated with these MIE TEC funds are budgeted in the Enabling R&D subprogram.

	FY 2007 vs. FY 2006 ($000)
National Spherical Torus Experiment (NSTX)	
The increase will allow NSTX to conduct 12 weeks of operation after carrying out 11 weeks of operation in FY 2006.	+282
National Compact Stellarator Experiment (NCSX)	
The request supports the current approved baseline...	-1,119
GPP/GPE/Other	
This increase will allow continued improvement of the physical infrastructure at PPPL and continue the process of moving fusion facilities from the Y-12 site to the X-10 site at ORNL.	+741
ITER Preparations	
ITER Preparations funding ends in FY 2006.	-5,835
U.S. Contributions to ITER (MIE Total Estimated Cost)	
This increase provides for the second year of funding for the Major Item of Equipment project consistent with the revised preliminary cost and schedule estimate. Funds are provided for major procurements of long-lead materials such as Nb3Sn superconductor and conduits as well as blanket materials. Funds are provided for U.S. scientists assigned to the ITER Organization abroad and associated infrastructure needs. Funds are also provided for design and procurement preparations for all components for which the United States is responsible.	+21,134
Total Funding Change, Facility Operations	**+18,019**

Enabling R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Enabling R&D			
Engineering Research	21,382	16,694	15,495
Enabling R&D for ITER (Other Project Costs)	—	3,449	23,000
Materials Research	7,338	7,043	4,687
Total, Enabling R&D	28,720	27,186	43,182

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 experiment 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 Office of Basic Energy Sciences 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 2007, 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. In addition, consistent with the direction that was started in FY 2006, selected efforts will be redirected from both the Engineering Research and Materials Research categories to the Enabling R&D for ITER support category to concentrate on specific R&D supporting U.S. responsibilities for ITER procurement packages. These funds will be reoriented for R&D support in a number of areas, including magnets, first wall/shield modules, tritium processing, fueling and pumping, heating and current drive components, and diagnostics, which directly support our ITER hardware contributions. Most of the remaining resources in these two categories will be focused on getting ready to use ITER as a test bed for technology research and to address potential issues that may occur during ITER operation.

Technology Accomplishments

A number of technological advances were made in FY 2005. Examples include:

- As part of the U.S.-Japan (DOE-JAEA) fusion materials collaboration, a wide range of mechanical property specimens of the latest generation of high-performance reduced-activation steels were tested following exposure to fusion-relevant conditions in the High Flux Isotopes Reactor at ORNL. These materials are leading candidates for the structures of ITER test blanket modules and future demonstration fusion energy machines. These results demonstrate the superior performance of these materials under intense neutron irradiation compared to conventional steels, and offer significant improvement in performance compared to steels developed in the 1990s.
- The University of California, Los Angeles (UCLA) completed a first series of magnetohydrodynamic (MHD) experiments aimed at providing scientific understanding and quantitative data on the motion of liquid metal free surface flows under complex magnetic field environments typical of tokamak divertors. These studies are particularly valuable for understanding

the flow behavior of the liquid surface divertor experiment being developed as a particle and heat load control technology for NSTX. The experiments were aided by an extensive numerical simulation effort using a unique 3-D, multi-physics, free-surface liquid metal MHD simulation code (HIMAG) developed in collaboration between UCLA and Hypercomp - an SBIR grantee. The experiments and numerical modeling have helped to build a strong understanding of the flow regime and the unique phenomena that characterize these MHD free surface flows, and at the same time provide a unique test bed for continuing to study other integrated phenomena including coupling to plasma currents and momentum.

- Experiments in the Plasma Interaction with Surface and Components Experimental Simulator (PISCES) facility at the University of California, San Diego, in collaboration with European laboratories, have observed the formation of tungsten-beryllide alloys on tungsten surfaces exposed to beryllium during deuterium plasma bombardment. The $Be_{12}W$ alloy appears to be the most stable beryllide and has a melting temperature of only about 1,500°C. The plasma-material interaction properties of the beryllide alloys are now being systematically investigated with regard to their formation and consequences for ITER operation.
- ORNL, in collaboration with the Joint European Torus (JET) group, designed, built, and tested an ITER-like High Power Prototype Antenna. Based on results from the test, a full power antenna was designed in collaboration with JET. JET is fabricating and will be installing this antenna.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Engineering Research	**21,382**	**16,694**	**15,495**
▪ **Plasma Technology**	**18,403**	**14,205**	**12,945**

Plasma Technology efforts will focus its resources on developing enabling technologies for both current and future machines, and on addressing potential ITER operational issues in the area of plasma materials interactions. The remaining resources will be used to complete a U.S.-Japan Collaborative Program on blanket materials for use in future experiments and in testing high efficiency gyrotrons. In FY 2007, $1,260,000 is redirected to support the ITER Other Project Costs (OPC) R&D efforts. During FY 2007, the following specific elements will be completed:

- Testing of a highly efficient (over 50 %) 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, will be completed.
- Studies will continue in the PISCES facility at UCSD, and the Tritium Plasma Experiment at INL, of tungsten-carbon-beryllium mixed materials layer formation and redeposition with attached hydrogen isotopes, and results will be applied to evaluate tritium accumulation in plasma facing components that will occur during ITER operation.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

- In the STAR facility at INL, the final series of material science experiments will be completed under the current cost-sharing collaboration with Japan (Jupiter II) 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.

	FY 2005	FY 2006	FY 2007
▪ **Advanced Design**	**2,979**	**2,489**	**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. A system study, based on the NCSX design of a compact stellarator power plant, will be completed.

	FY 2005	FY 2006	FY 2007
Enabling R&D for ITER (Other Project Costs)	**—**	**3,449**	**23,000**

Enabling R&D funds for ITER activities are identified in FY 2007 for R&D and design in support of equipment in a number of areas including magnets R&D and design, plasma facing components, tritium processing, fueling and pumping, heating and current drive components, materials, and diagnostics, which would be provided by the U.S. to ITER. The FY 2007 OPC funding level is slightly increased from the FY 2006 President's Budget to accommodate the domestic and international ITER project priorities due to the delayed start for ITER. The results of this R&D and design are also broadly applicable to future burning plasma experiments. These activities are directly associated with the ongoing base program and while they will be carried out by scientists and technologists as part of their ongoing efforts, once reorientation to ITER has been accomplished, these activities will be carried out using DOE Order 413.3 project management tools for controlling schedule, cost and scope, as well as through international collaboration as appropriate.

It is the objective of the international ITER parties to obtain the negotiators' acceptance of the ITER Agreement by March 2006 and to obtain governmental signatures on the completed ITER Agreement later in FY 2006. The Agreement finalizes the allocation of equipment to be provided by each ITER Party and finalizes the concept for the mode of operation among the ITER Parties and central project team during the construction, operation and decommissioning phases of the ITER program. The MIE project cost estimates for U.S. Contributions to ITER, including the Other Project Cost activities, are preliminary until the baseline scope, cost and schedule for the MIE project are established.

For the most part, the OPC activities are accomplished by focusing existing scientists and technologists on specific ITER tasks in a project mode. Based on the funding profile for these activities shown below, additional funds will be required for FY 2007-2009 in this subprogram. During FY 2007, the following specific elements will be continued, following progress in FY 2006:

- Conduct R&D/design to support fabrication of the first wall shield module for ITER.
- Conduct R&D/design to support fabrication of superconducting strand and jacket material for the ITER Central Solenoid.

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

- Conduct R&D/design to support fabrication of two key systems, the high throughput continuous extruder and centrifuge accelerator, of the ITER Pellet Injector.
- Conduct R&D/design to support fabrication of the ITER Fuel Cleanup System and develop a dynamic process modeling code of the ITER tritium system.
- Conduct R&D/design to support fabrication of the ITER heating ICRH antenna.
- Conduct R&D/design to support fabrication of the ITER 1 MW, 120 GHz start-up gyrotron.
- Conduct R&D to support selection of different materials and components necessary for ITER diagnostics

U.S. Contributions to ITER Financial Schedule Other Project Costs (OPC)[a]

(budget authority in thousands)

Fiscal Year	Other Project Costs[b]
2006	3,449
2007	23,000
2008	10,500
2009	6,000
2010	1,500
2011	500
Total	44,949

	FY 2005	FY 2006	FY 2007
Materials Research	**7,338**	**7,043**	**4,687**

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 Fusion Energy Sciences research program. The FY 2007 request will maintain a small, but highly beneficial Materials Research program that addresses material needs for 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.

	FY 2005	FY 2006	FY 2007
Total, Enabling R&D	**28,720**	**27,186**	**43,182**

[a] The funding profile is a preliminary estimate incorporating the key results of the December 2005 negotiations. In addition, shifts between OPC and TEC funding have been made consistent with the intentions of DOE 413.3 to provide for R&D and design in support of the MIE project. During FY 2006, several U.S. reviews are scheduled to validate the preliminary cost and schedule profile for the U.S. Contributions to ITER MIE project. In addition, international ITER Project activities in FY 2006 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-2 planned for September 2007.
[b] Note that the MIE TEC funding associated with these Other Project Costs is budgeted in the Facility Operations subprogram.

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Engineering Research	
▪ **Plasma Technology**	
The decrease is due to a redirection to R&D for ITER (MIE OPC) for efforts in magnets, first wall/shield modules, heating and fueling technologies, tritium processing, materials, and diagnostics. Work on a U.S. Test Blanket Module for ITER will be phased out.	-1,260
▪ **Advanced Design**	
Funding supports slight increases in Virtual Laboratory for Technology management costs.	+61
Total, Engineering Research	**-1,199**
Enabling R&D for ITER (Other Project Costs)	
Funding increases are consistent with the revised preliminary cost and schedule estimate for the ITER MIE project. Funds have been redirected from Plasma Technology and Materials elements to focus efforts in support of ITER in the magnet, first wall/shield modules, tritium processing, fueling and pumping, heating and current drive components, materials, and diagnostics areas. The FY 2007 OPC funding level is further increased from the profile contained in the FY 2006 President's Budget to accommodate the domestic and international ITER project priorities due to the slowed start for ITER.	+19,551
Materials Research	
The decrease is due to a redirection to R&D for ITER (MIE OPC) for efforts in magnets, first wall/shield modules, heating and fueling technologies, tritium processing, materials, and diagnostics.	-2,356
Total Funding Change, Enabling R&D	**+15,996**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
General Plant Projects	1,643	1,791	1,810
Capital Equipment	24,279	37,801	57,765
Total, Capital Operating Expenses	25,922	39,592	59,575

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 2005	FY 2006	FY 2007	Completion Date
NCSX	101,971	92,401	23,818	17,500	17,019	15,900	FY 2009[a]
U.S. Contributions to ITER	1,122,000[b]	1,077,051[b]	—	—	15,866	37,000	FY 2014
Total, Major Items of Equipment				17,500	32,885	52,900	

[a] The FY 2006 Congressional budget reflected an estimated increase to the TEC for NCSX to $90,839,000, with an estimated completion date of May 2009. The project was formally rebaselined in July, 2005 consistent with the funding profile requested in the FY 2006 budget. The new baseline TEC is $92,401,000, with completion in July 2009.

[b] Funding is for the second year of the Major Item of Equipment project, U.S. Contributions to ITER. These figures are preliminary estimates, though the TPC for U.S. Contributions to ITER would change only if OMB-established inflation rates change between now and when the performance baseline for scope, cost, and schedule is established after the ITER International Agreement is completed, and if currency exchange rates change affecting about 15% of the TPC funding. The estimates have been prepared based upon (1) U.S. industrial estimates for the hardware items the United States is likely to contribute, (2) FES 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) FES 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 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Science Laboratories Infrastructure					
Laboratories Facilities Support	21,448	22,389	-224[a]	22,165	29,461
Excess Facilities Disposition	6,051	14,637	-146[a]	14,491	16,348
Oak Ridge Landlord	5,039	5,079	-51[a]	5,028	5,079
Health & Safety Improvements	4,960	—	—	—	—
Total, Science Laboratories Infrastructure	37,498[b]	42,105	-421	41,684	50,888

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act"
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 enable the conduct of Departmental research missions at the ten Office of Science (SC) laboratories and the Oak Ridge Institute for Science and Education (ORISE) by funding line item construction, general plant projects, maintenance activities, and clean-up and removal of excess facilities to maintain the general purpose infrastructure (GPI). The program also supports SC stewardship responsibilities for over 24,000 acres of the Oak Ridge Reservation (ORR), including the Federal facilities in the town of Oak Ridge; 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); and provides funding for correction of deficiencies identified by the Occupational Safety & Health Administration (OSHA) and the Nuclear Regulatory Commission (NRC), and for implementation of recommendations to improve health and safety practices at SC laboratories.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs, but with additional efforts from subprograms which support the GPRA Units in carrying out their missions.

Benefits

This program supports the conduct of Departmental research missions at SC laboratories and the ORR, primarily by addressing general purpose facilities and infrastructure needs.

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.
[b] Total is reduced by $4,500,000 for a reprogramming to High Energy Physics and $338,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.

Significant Program Shifts

Progress in Line Item Projects – In FY 2005, two subprojects were completed: The ORNL Research Support Center and the ANL-E Mechanical and Control Systems Upgrades, Phase I.

Funding is requested to initiate design and construction of four infrastructure projects:

- The Seismic Safety Upgrade of Buildings, Phase I, project at the Lawrence Berkeley National Laboratory (LBNL);
- The Modernization of Building 4500N, Wing 4, Phase I, project at the Oak Ridge National Laboratory (ORNL);
- The Building Electrical Services Upgrade, Phase II, project at the Argonne National Laboratory (ANL); and
- The Renovate Science Laboratory, Phase I, project at the Brookhaven National Laboratory (BNL).

FY 2007 funding for the Pacific Northwest National Laboratory (PNNL) Physical Sciences Facility is requested in the Defense Nuclear Non-Proliferation Research and Development program. Work will continue on preliminary and detailed design.

External Independent Reviews

Beginning in FY 2005, the costs of conducting External Independent Reviews (EIRs) for Capital Asset Projects greater than $5,000,000 within SC have been 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

Laboratories Facilities Support

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Laboratory Facilities Support			
General Purpose Facilities	17,168	12,376	14,671
Environment, Safety and Health	2,528	5,314	13,270
Payment in Lieu of Taxes (PILT)	1,752	1,505	1,520
General Plant Projects (GPP)	—	2,970	—
Total, Laboratories Facilities Support	21,448	22,165	29,461

Description

The Laboratories Facilities Support (LFS) subprogram supports the mission of the Office of Science (SC) by providing funding for line item construction, general plant projects and maintenance activities to maintain the general purpose infrastructure, correction of safety deficiencies identified by OSHA and NRC, and 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. The subprogram also provides PILT assistance, as required by law, for communities surrounding 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.

As has been reported previously, the ten SC research laboratories, and the Oak Ridge Institute for Science and Education (ORISE), together have more than 1,400 buildings and 103 real property trailers, with 20 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 33 years. In terms of square footage, 44.6% (8.8 million square feet) that is forty years old or older, including 23.7% (4.7 million square feet) that is over fifty years old.

As required by DOE Order 430.1B, Real Property Asset Management, of September, 2003, SC laboratories have developed Ten Year Site Plans (TYSPs), which identify and prioritize projects, activities, and mission resource requirements for real property assets over a ten-year period. The Integrated Facilities and Infrastructure (IFI) Crosscut Budget forms the first five years of each TYSP. The SC TYSPs identify a need for over a billion dollars of line item and GPP funding to fully modernize and revitalize the sites' infrastructure over the ten-year period.

The large backlog of construction needs is 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 40's and 50'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 sensitivity and temperature variability, and improved air quality for, and increased power demand by, 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, 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 subprojects proposed for funding by the LFS subprogram are scored using the DOE Cost-Risk-Impact Matrix, that takes into account risk, impacts, and mission need. The subprojects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process. After prioritization by the LFS subprogram, the subprojects are evaluated further for SC science program mission impact by an integrated infrastructure management team composed of representatives from the LFS subprogram and SC research program offices.

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, both of the subprojects completed in FY 2005 were completed within their cost, scope, and schedule baselines.

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. DOE's December 2000 report to Congress, "The US 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 2005	FY 2006	FY 2007
General Purpose Facilities	**17,168**	**12,376**	**14,671**

Provides initial funding for three projects identified below. More detail is provided in Project Engineering and Design data sheet 07-SC-04, and construction project data sheet MEL-001.

New starts:

- Modernization of Building 4500N, Wing 4, Phase I, at ORNL, which will rehabilitate a facility housing many of the laboratory's chemical laboratory facilities, as well as administrative offices and the medical clinic ($7,071,000);
- Building Electrical Services Upgrade, Phase II, at ANL, which will upgrade critical portions of the electrical power distribution system in twelve research buildings and support facilities, including the Canal Water Plant supplying cooling water for site experiments ($3,000,000);
- 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 ($4,600,000).

Environment, Safety and Health	**2,528**	**5,314**	**13,270**

Provides final funding to support the completion of one subproject, and initial funding for the Seismic Safety Upgrade of Buildings, Phase I, at LBNL. More detail is provided in Project Engineering and Design data sheet 07-SC-04, and construction project data sheet MEL-001.

Ongoing:

- Safety and Operational Reliability Improvements at SLAC, which will replace deteriorated sections of underground utilities and install seismic upgrades necessary to bring various building structures into compliance with the seismic standards of the Uniform Building Code. ($5,770,000)

New starts:

- Seismic Safety Upgrade of Buildings, Phase I, at LBNL, which will address the seismic vulnerability of laboratory buildings where high life-safety risks have been identified ($7,500,000)

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 cutting edge research throughout the SC Laboratory complex. Funding for this GPP activity in FY 2007 is contained in other SC programs' budgets.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Payment in Lieu of Taxes (PILT)	**1,752**	**1,505**	**1,520**

Provide PILT to support assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory. PILT payments are negotiated between the Department and local governments based on land values and tax rates.

	FY 2005	FY 2006	FY 2007
Total, Laboratories Facilities Support	**21,448**	**22,165**	**29,461**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
General Purpose Facilities (GPF)	
▪ Increase is due to the initiation of funding for the three new subprojects, two subprojects received final funding in FY 2006.	+2,295
Environmental Safety & Health (ES&H)	
▪ Increase is due to the start of the LBNL Seismic Safety Upgrade of Buildings, Phase I, and a ramp-up of funding for the SLAC Safety and Operational Reliability Improvements subproject per the construction funding plan.	+7,956
GPP	
GPP activities are supported in other SC program budgets in FY 2007.	-2,970
PILT	
▪ PILT funding is maintained.	+15
Total Funding Change, Laboratories Facilities Support	**+7,296**

Excess Facilities Disposition

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Excess Facilities Disposition	6,051	14,491	16,348

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 cleans-up 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 and reducing expenditures on surveillance and maintenance of excess facilities.

Supporting Information

The EFD subprogram evaluates and prioritizes the backlog based on footprint reduction, risk reduction (e.g., removal of hazards), availability of space/land for research activities, and cost savings (e.g., elimination of surveillance and maintenance costs). The prioritized list is further evaluated for mission impact by an integrated infrastructure management team representing the EFD subprogram and SC research program offices. The estimated backlog of non-contaminated or slightly contaminated facilities at the beginning of FY 2007 will be approximately $100,000,000, including approximately $70,000,000 of work to decontaminate and decommission (D&D) the remainder of the Bevatron Complex at the Lawrence Berkeley National Laboratory (LBNL).

In FY 2007, the EFD subprogram will continue D&D of the Bevatron. This effort, whose total cost is estimated to range from $67,000,000 to $84,000,000, will, by FY 2011, eliminate a legacy facility which ceased operation in 1993, and free up 127,000 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 the Bevatron will free up land for re-development to support on-going and new mission work.

The EFD subprogram will also demolish contaminated, legacy facilities at 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. These facilities include Building 650 at BNL, and Buildings 2018, 3008, and 3111 at ORNL.

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 project.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Excess Facilities Disposition	**6,051**	**14,491**	**16,348**

In FY 2005, funding of $6,051,000 supported the projects listed below and allowed for the clean-up/removal of an estimated 100,000 square feet of space:

- Ames ($150,000) – Waste Handling Facility Closeout and Demolition, Phase 2, and Demolition of the Hydrogen Test Cell Facility (approximately 900 square feet)
- ANL-E ($1,457,000) – Bldg. 202, Room Q-183 Former Animal Injection Laboratory Remediation, Bldg. 202, W-Wing (W-036, W-123, W-127, W-135) Demolition, Bldg. 370 Alkali Metal Loop Demolition, Bldg. 40 Demolition, Phase 1, Bldg. 205 K-116 Remediation and Bldg. 325C Demolition (approximately 3,600 square feet)
- BNL ($405,000) – Demolition of Buildings 428, 118B, 933B, 934 and Partial Demolition of Buildings 197 and 527 (approximately 6,400 square feet)
- FNAL ($125,000) – Demolition of Buildings 903, 951, 993, T009, T023, T115, T158, T072, 144, 145, 146, 147 and 947 (approximately 5,800 square feet)
- LBNL ($1,360,000) – Development of Conceptual Design, Environmental and CD-1 Documentation for the Bevatron Disposition Project
- LLNL ($150,000) – Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase 2 (approximately 4,000 square feet)
- ORISE ($565,000) – Demolition of Building 26 (approximately 12,800 square feet)
- ORNL ($1,688,000) – Demolition of Buildings 1000, XH1326, XH1401 and XH1327 (approximately 67,000 square feet)
- PPPL ($55,000) – Demolition of Health Physics Calibration and Service Laboratory (approximately 2,200 square feet)
- Other miscellaneous projects ($96,000)

In FY 2006, funding of $14,491,000 will support the projects listed below and allow for the clean-up/removal of an estimated 87,000 square feet of space:

- Ames ($45,000) – Waste Handling Facility Closeout and Demolition (9,000 square feet)
- ANL-E ($770,000) – Bldg. 374A Demolition Project, Demolition of Bldg 40, Phase II, and Site Beryllium Remediation, Heavy Isotopes Hood/Equipment Demolition and Bldg. 205 F-111 (approximately 11,000 square feet)
- BNL ($600,000) – Demolition of Buildings 86, 527, Phase II, 422 (partial), 650A, 628, 492, and Demolition of Building 650, Phase I (approximately 18,000 square feet)
- FNAL ($125,000) – Demolition of Two Muon Enclosures (approximately 800 square feet)

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

- LBNL ($10,900,000) – This funding will support activities required to execute total removal of the Building 51/Bevatron complex, including: surveys and planning activities, such as engineered plans and specifications for the demolition of the Bevatron and Building 51; waste management plan; characterization plan; health & safety plan; and community relations plan. The FY 2006 funding will also support utility relocations, preliminary hazardous material abatement, and removal of abandoned electrical equipment
- LLNL ($150,000) – Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase 3 (approximately 7,000 square feet)
- ORISE ($768,000) – Demolition of Building SC-5, Large Animal Containment Facility (approximately 5,600 square feet)
- ORNL ($858,000) – Demolition of Solway and Freels Bend Excess Facilities (approximately 36,000 square feet)

FY 2006 funding also includes $275,000 to conduct External Independent Reviews (EIRs) of SLI construction projects.

In FY 2007, funding of $16,348,000 will support the projects listed below, allowing the clean-up/removal of an estimated 22,000 square feet of space:

- ANL-E ($500,000) – Building 205 F-111 Vault Cleanup & Hood Demolition (Phase 3 Vault/Corridor Cleanup)
- BNL ($697,000) – Continued demolition of Building 650
- 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.

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	**6,051**	**14,491**	**16,348**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Excess Facilities Disposition	
▪ The increase is primarily for demolition of the Bevatron (+$3,100,000), offset by a reduction in funding for demolition or cleanup for re-use of excess or unusable facilities other than the Bevatron (-$1,243,000).	+1,857

Oak Ridge Landlord

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Oak Ridge Landlord	5,039	5,028	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 Office (ORO).

Benefits

This subprogram maintains continuity of operations at the Oak Ridge Reservation and the Oak Ridge Office by minimizing interruptions due to infrastructure and/or other systems failures. The subprogram also provides Payment in Lieu of Taxes (PILT) assistance as required by law for communities surrounding 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, plus DOE facilities in the town of Oak Ridge. This includes roads and grounds and other infrastructure maintenance, environment, safety and health (ES&H) support and improvements, PILT for Oak Ridge communities, and other needs related to landlord requirements. These activities maintain continuity of operations at the Oak Ridge Reservation and the ORO, and minimize interruptions due to infrastructure and/or other systems failures.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Roads, Grounds and Other Infrastructure and ES&H Support and Improvements	**2,448**	**1,781**	**2,051**

Road maintenance, reservation mowing, and bridge inspections.

General Purpose Equipment (GPE)	**—**	**219**	**—**

Purchase of heavy equipment (e.g., bulldozer, dump truck, and road roller).

General Plant Projects (GPP)	**—**	**200**	**200**

Major road repair.

Payment in Lieu of Taxes (PILT)	**2,300**	**2,550**	**2,550**

PILT to the City of Oak Ridge, and Anderson and Roane Counties.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Reservation Technical Support	**291**	**278**	**278**

Includes meteorological monitoring system, public warning siren system, ORR command media, and records management.

Total, Oak Ridge Landlord	**5,039**	**5,028**	**5,079**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Oak Ridge Landlord	
Additional funds are provided to support an increase in maintenance and repair of ORO-managed roads (+$270,000) offset by decrease from one time GPE funding in FY 2006 for heavy equipment to be used for road repair (-$219,000).	+51

Health and Safety Improvement

Funding Schedule by Activity

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
Health and Safety Improvement	4,960	—	—

Description

The Health and Safety Improvements subprogram corrects health and safety deficiencies at SC laboratories to ensure consistency with Occupational Safety and Health Administration (OSHA) and Nuclear Regulatory Commission (NRC) requirements.

Benefits

This subprogram improves health and safety practices at SC laboratories to ensure consistency with Occupational Safety and Health Administration and Nuclear Regulatory Commission safety requirements.

Detailed Justification

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
Health and Safety Improvements	**4,960**	**—**	**—**

In FY 2003, Congress directed the NRC and OSHA to perform inspections at the 10 SC laboratories. The purpose of these inspections was to identify those deficiencies that would need to be corrected if the Department were regulated by these agencies, and to provide recommendations for improved health and safety practices.

The NRC and OSHA inspections were performed in FY 2003 and FY 2004. Most of the deficiencies identified by the NRC were of administrative nature that would have to be corrected if the SC laboratories became regulated by the NRC. The OSHA inspections identified numerous safety deficiencies, including problems with electrical hazards, machine guarding, legacy material removal, material handling, ladder compliance, inadequate building egress, crane hazards, exhaust ventilation, and eyewash station availability and operability. To correct these deficiencies, SLI funding was provided to the affected laboratories in FY 2004 and FY 2005.

The Health and Safety Improvements subprogram was discontinued in FY 2006 because most of the OSHA findings have been corrected, and correction of remaining deficiencies will be funded by the laboratories, primarily via overhead.

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Plant Projects	—	3,170	200
General Purpose Equipment	—	219	—
Total, Capital Operating Expenses	—	3,389	200

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2005	FY 2006	FY 2007	Unapprop. Balance
07-SC-04 Science Laboratories Infrastructure, Project Engineering Design	N/A	N/A	—	—	8,908	—
04-SC-001 Science Laboratories Infrastructure, Project Engineering Design	N/A	986	4,960	2,970	—	—
03-SC-001, Science Laboratories Infrastructure, Project Engineering Design.	N/A	1,089	313	—	—	—
MEL-001, Science Laboratories Infrastructure Project	N/A	N/A	14,423	14,720	19,033	47,829
Total, Construction/PED			19,696	17,690	27,941	

07-SC-04 – Science Laboratories Infrastructure, Project Engineering Design (PED), Various Locations

1. Significant Changes

These projects are being proposed as FY 2007 new starts.

2. Design, Construction and D&D Schedule

See subproject details.

3. Baseline and Validation Status

See subproject details.

4. Project Description, Justification and Scope

This project funds PED for two types of subprojects:

- Projects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service and support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Projects to correct Environment, Safety and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades and electrical system replacements.

This PED request is for design funding for the Seismic Safety Upgrade of Buildings, Phase I, (LBNL), Building Electrical Service Upgrade, Phase II (ANL), Renovate Science Laboratories, Phase I (BNL), and Modernization of Laboratory Building 4500N, Wing 4 (ORNL).

New Project Starts

Environment, Safety and Health:

a. 07-SC-0401 MEL-001-047 Seismic Safety Upgrade of Buildings, Phase I, LBNL

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q FY 2007	3Q FY 2008	3Q FY 2008	4Q FY 2010	2,500	17,000

Fiscal Year	Appropriations	Obligations	Costs
2007	2,500	2,500	1,460
2008	—	—	1,040

The proposed Seismic and Structural Safety Upgrades of Buildings, Phase I, subproject will correct existing structural deficiencies in LBNL Buildings 50 and 74, enhancing the safety of over 600 occupants of the seismically deficient buildings. Each of these buildings has been assigned a "Poor" seismic performance rating per the University of California Seismic Safety rating system. A “Poor” seismic performance rating applies to buildings and other structures whose performance during a major seismic disturbance is anticipated to result in significant structural and non-structural damage and/or falling hazards that would represent appreciable life safety hazards. Proposed upgrades vary by building and include: column reinforcement, new tube bracing, connection and anchorage upgrades, reinforcing interior shear walls, supplemental vertical supports, gap enlargement between structures, new footings, and upgrades to structural exterior walls.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007.........	17,000	325	—	17,325	—	17,325

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2005
- Critical Decision-1: Approve Preliminary Baseline Range—4Q FY 2006
- External Independent Review Final Report—4Q FY 2007
- Critical Decision-2: Approve Performance Baseline—1Q FY 2008
- Critical Decision-3: Approve Start of Construction—3Q FY 2008
- Critical Decision-4: Approve Start of Operations—4Q FY 2010

General Purpose Facilities Projects:

b. 07-SC-0403 MEL-001-049 Building Electrical Service Upgrade – Phase II, ANL

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q FY 2007	2Q FY 2008	4Q FY 2008	4Q FY 2011	1,250	17,000

Fiscal Year	Appropriations	Obligations	Costs
2007	1,250	1,250	1,000
2008	—	—	250

This project will upgrade critical portions of the electrical power distribution systems in multiple research buildings (18) and their support facilities (5). It includes medium voltage transfer and feeder switches, area loop switches, overhead lines, panel-boards, transformers, switches, controls and switchgear/bus ducts. It will upgrade the electrical systems to current safety standards, improve systems reliability and performance, and reduce facility maintenance and repair costs.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007.........	17,000	100	—	17,100	—	17,100

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—FY 2002
- Critical Decision-1: Approve Preliminary Baseline Range—FY 2007
- External Independent Review Final Report—TBD
- Critical Decision-2: Approve Performance Baseline—4Q FY 2007
- Critical Decision-3: Approve Start of Construction—4Q FY 2008
- Critical Decision-4: Approve Start of Operations—4Q FY 2011

c. 07-SC-0404 MEL-001-050 Renovate Science Laboratories, Phase I, BNL

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
2Q FY 2007	3Q FY 2008	4Q FY 2008	4Q FY 2011	3,158	18,000

Fiscal Year	Appropriations	Obligations	Costs
2007	3,158	3,158	1,525
2008	—	—	1,633

This project will upgrade and rehabilitate existing, obsolete, and unsuitable BNL Laboratory facilities into modern, efficient laboratory spaces. This project will revitalize and modernize laboratories in 5 buildings. The scope will include HVAC, electrical, lighting, plumbing, laboratory service, support and work areas, and architectural surface upgrades.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007.........	18,000	200	—	18,200	—	18,200

The Performance Baseline is expected to be validated prior to the use of construction funds. No construction funds will be used until the Performance Baseline has been validated as required by DOE M-413.3-1.

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—2Q FY 2006
- Critical Decision-1: Approve Preliminary Baseline Range—4Q FY 2006
- External Independent Review Final Report—TBD
- Critical Decision-2: Approve Performance Baseline—4Q FY 2007
- Critical Decision-3: Approve Start of Construction—3Q FY 2008
- Critical Decision-4: Approve Start of Operations—1Q FY 2011

d. 07-SC-0402, MEL-001-024 Modernization of Laboratory, Building 4500N, Wing 4 Oak Ridge National Laboratory (ORNL)

Fiscal Quarter				Total Estimated Cost (Design Only) ($000)	Full Total Estimated Cost Projection
A-E Work Initiated	A-E Work Completed	Physical Construction Start	Physical Construction Complete		
1Q FY 2007	1Q FY 2008	1Q FY 2008	3Q FY 2010	2,000	18,000

Fiscal Year	Appropriations	Obligations	Costs
2007	2,000	2,000	1,500
2008	—	—	500

This project is to modernize Wing 4 Building 4500N. This constitutes approximately 25% of the approximately 342,000 square feet contained in the existing structure. Wing 4 provides space for laboratories with the associated offices and the necessary support functions for the researchers. There will be minimal impact to the structural members of the building. In general the interior architectural features of the facility will be demolished. This includes all non-load bearing interior walls, floor and ceiling finishes, furnishings and specialties such as laboratory equipment, toilet room fixtures and partitions, mechanical and electrical equipment.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007.........	18,000	260	—	18,260	—	18,260

The Performance Baseline is expected to be validated by 3Q 2007. No construction funds will be used until the Performance Baseline has been validated as required by DOE M-413.3-1.

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—March 2002
- Critical Decision-1: Approve Preliminary Baseline Range—FY 2006
- External Independent Review Final Report—3Q FY 2007

- Critical Decision-2: Approve Performance Baseline—3Q FY2007
- Critical Decision-3a: Approve Start of Early Construction (Limited Demolition)—4Q FY 2007
- Critical Decision-3b: Approve Start of Major Construction—1Q FY 2008
- Critical Decision-4: Approve Start of Operations—3Q FY 2010

5. Financial Schedule (dollars in thousands)

	Appropriations	Obligations	Costs
Design by Fiscal Year			
2007	8,908	8,908	5,485
2008	—	—	3,423
Total, Design PED (07-SC-04)	8,908	8,908	8,908

6. Details of Project Cost Estimate

See project details.

7. Schedule of Project Costs

See project details.

8. Related Operations and Maintenance Funding requirements

Not applicable for project engineering and design.

(Related Funding Requirements)

Not applicable for project engineering and design.

9. Required D&D Information

Not applicable for project engineering and design.

10. Acquisition Approach

Design services will be obtained through competitive and/or negotiated contracts. M&O contractor staff may be utilized in areas involving security, production, proliferation, etc. concerns.

MEL-001 – Science Laboratories Infrastructure Project, Various Locations

1. Significant Changes

N/A

2. Design, Construction, and D&D Schedule

See subproject details.

3. Baseline and Validation Status

See subproject details.

4. Project Description, Justification and Scope

MEL-001 subprojects are typical conventional construction and as such can be engineered, designed, and ready for construction contract award within one fiscal year, or in the following fiscal year. Accordingly, these subprojects are submitted with both PED and construction funding identified. In most cases these subprojects proceed (after normal reviews and approvals) directly from design into construction with no delay. DOE's December 2000 Report to Congress "The US 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.

This project funds two types of subprojects:

- Subprojects that renovate or replace inefficient and unreliable general purpose facilities (GPF) including general use, service, and user support facilities such as administrative space, cafeterias, utility systems, and roads; and
- Subprojects to correct Environment, Safety, and Health (ES&H) deficiencies including deteriorated steam lines, environmental insult, fire safety improvements, sanitary system upgrades, and electrical system replacements.

They are grouped by these categories below:

General Purpose Facilities Projects:

a. Subproject 27 – Research Support Building, Phase I (BNL)

TEC	Prev.	FY 2005	FY 2006	FY 2007	Outyear	Construction Start/ Completion Dates
18,200	8,191[a]	6,363	3,646	—	—	2Q 2005–3Q 2007

This 65,000 sq. ft. facility is intended to consolidate Staff Services, Public Affairs, Human Resources, Credit Union, Library, and other support functions in a central quadrangle to provide staff and visiting scientists with convenient and efficient support. This facility, the first of four phases in the BNL Master Revitalization Plan, will include a lobby with a visitor information center to assist visiting scientists, and a coordinated office layout of related support services. After

[a] Title I and Title II Design funding of $1,679,000 provided under PED Project No. 03-SC-001.

completion of this subproject, 16,400 sq. ft. of World War II era structures will be torn down. Based on total life-cycle costs, productivity gains, avoided energy and maintenance costs, the Research Support Building will provide a return on investment of 10% and a simple payback of 8.4 years.

The subproject is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2005........	18,200	70	—	18,270	18,200	—
FY 2006........	18,200	70	—	18,270	18,200	—
FY 2007........	18,200	70	—	18,270	18,200	—

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—1Q FY 2001
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2003
- Critical Decision-2: Approve Performance Baseline—3Q FY 2004
- External Independent Review Final Report—3Q FY 2004
- Critical Decision-3: Approve Start of Construction—2Q FY 2005
- Critical Decision-4: Approve Start of Operations—3Q FY 2007

b. Subproject 28 – Building 77 Rehabilitation of Structures and Systems, Phase II (LBNL)

TEC	Prev.	FY 2005	FY 2006	FY 2007	Outyear	Construction Start/ Completion Dates
13,360	3,735[a]	5,845[b]	3,780	—	—	3Q 2005 – 2Q 2007

This subproject will provide for rehabilitation to correct mechanical, electrical and architectural deficiencies in Buildings 77 (a 39 year old, 68,000 sq. ft. high-bay industrial facility) and 77A (a 14 year old, 10,000 sq. ft. industrial facility). Both buildings house machine shop and assembly operations in which production of highly sophisticated research components for a variety of DOE research projects is performed. Current work includes precision machining, fabrication and assembly of components for the Advanced Light Source, the Dual-Axis Radiographic Hydrodynamic Test Facility (DAHRT) project, the Spallation Neutron Source, and the ATLAS Detector. Infrastructure systems installed by this subproject will include HVAC, power distribution, lighting, and noise absorption materials. The improvements are necessary to satisfy urgent demands for high levels of cleanliness, temperature and humidity control, and OSHA and reliability requirements. This is the second of two subprojects; the first subproject, funded in FY 1999 and completed in FY 2002, corrected structural deficiencies in Building 77.

The subproject is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

[a] Title I and Title II Design Funding of $1,089,000 provided under PED Project no. 03-SC-001.
[b] Title I and Title II Design Funding of $313,000 provided under PED Project no. 03-SC-001.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2005........	13,360	135	—	13,495	13,360	—
FY 2006........	13,360	135	—	13,495	13,360	—
FY 2007........	13,360	135	—	13,495	13,360	—

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—1Q FY 2001
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2003
- External Independent Review Final Report—2Q FY 2006
- Critical Decision-2: Approve Performance Baseline—2Q FY 2006
- Critical Decision-3: Approve Start of Construction—3Q FY 2006
- Critical Decision-4: Approve Start of Operations—1Q FY 2009

c. Subproject 49 – Building Electrical Services Upgrade – Phase II, ANL

TEC	FY 2005	FY 2006	FY 2007	Outyear	Construction Start/ Completion Dates
17,000	—	—	3,000[a]	14,000	4Q 2008 – 4Q 2011

This subproject will upgrade critical portions of the electrical power distribution systems within multiple research buildings (18) and their support facilities (5), at Argonne National Laboratory. The distribution system transfer and feeder switches, area loop switches, overhead lines, panel-boards, transformers, switches, controls, and 480V switchgear/bus ducts will be upgraded to current safety standards, improving systems reliability and performance, and reducing facility maintenance and repair costs.

The identified existing electrical distribution systems are approximately 30 to 40 years old, do not meet current environmental, safety and health standards, are of poor reliability, and are not adequate to fulfill the Laboratory's current missions.

The subproject is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007........	17,000	100	—	17,100	TBD	17,100

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—FY 2002

[a] Title I and Title II Design Funding of $1,250,000 provided under PED Project no. 07-SC-0403.

- Critical Decision-1: Approve Preliminary Baseline Range—FY 2007
- External Independent Review Final Report—TBD
- Critical Decision-2: Approve Performance Baseline—4Q FY 2007
- Critical Decision-3: Approve Start of Construction—4Q FY 2008
- Critical Decision-4: Approve Start of Operations—4Q FY 2011

d. Subproject 50 – Renovate Science Laboratories – Phase I, (BNL)

TEC	FY 2005	FY 2006	FY 2007	Outyears	Construction Start/ Completion Dates
18,000	—	—	4,600[a]	13,400	4Q 2008 – 1Q 2011

This project will upgrade and rehabilitate existing, obsolete, and unsuitable BNL Laboratory facilities into modern, efficient laboratory spaces. This project will revitalize and modernize laboratories in 5 buildings. The scope will include HVAC, electrical, lighting, plumbing, laboratory service, support and work areas, and architectural surface upgrades.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007	18,000	70	—	18,070	—	18,070

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—2Q FY 2006
- Critical Decision-1: Approve Preliminary Baseline Range—4Q FY 2006
- External Independent Review Final Report—TBD
- Critical Decision-2: Approve Performance Baseline—4Q FY 2007
- Critical Decision-3: Approve Start of Construction—3Q FY 2008
- Critical Decision-4: Approve Start of Operations—1Q FY 2011

e. Subproject 24 – Modernization of Laboratory, Building 4500N, Wing 4 Oak Ridge National Laboratory (ORNL)

TEC	FY 2005	FY 2006	FY 2007	Outyear	Construction Start/ Completion Dates
18,000	—	—	7,071[b]	10,929	4Q 2007 – 3Q 2010

This proposed renovation of the 4500 complex is a critical component of ORNL's Modernization Initiative. Building 4500N is intended to serve as one of the strategic laboratory/office facilities for ORNL's future. This project is to modernize Wing 4 of Building 4500N, about 25% of the

[a] Title I and Title II Design funding of $3,158,000 is provided under PED Project no. 07-SC-0404.
[b] Title I and Title II Design funding of $2,000,000 is provided under PED Project no. 07-SC-0402.

approximately 342,000 square feet contained in the existing structure. Wing 4 provides space for laboratories with the associated offices and the necessary support functions for the researchers. In general, the major structural members of the building will have minimal impact by this modernization. Only minor upgrades are required to the structural members of the building to meet seismic requirements. In general, the interior architectural features of the facility will be demolished. This includes all non-load-bearing interior walls, floor and ceiling finishes, furnishings, and specialties such as laboratory equipment, toilet room fixtures, and partitions. Mechanical and electrical equipment dedicated to servicing the modernized areas and any research related equipment will be removed. All associated service piping and ductwork will be removed.

Building 4500N is a two-story building with exterior walls constructed of brick veneer on concrete masonry units. A new roof was put on the building. The project will provide all new windows, interior walls, ceilings and floor finish, laboratory equipment, office and conference room furnishing, and restroom facilities, will meet Americans with Disabilities Act and be compliant with current national codes and standards. The new heating, ventilation, and air conditioning equipment will include energy conservation features such as re-circulating variable air volume units.

The subproject is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007........	18,000	260	—	18,260	—	18,260

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—2Q FY 2002
- Critical Decision-1: Approve Preliminary Baseline Range—3Q FY 2006
- External Independent Review Final Report—2Q FY 2007
- Critical Decision-2: Approve Performance Baseline—3Q FY 2007
- Critical Decision-3A: Approve Start of Early Construction (Limited Demolition) —4Q FY 2007
- Critical Decision-3B Approve Start of Major Construction—1Q FY 2008
- Critical Decision-4 Approve Start of Operations—3Q FY 2010

f. Subproject 51 – Physical Sciences Facility, PNNL

TEC	Prev.	FY 2005	FY 2006	FY 2007	Outyear	Construction Start/ Completion Dates
1,980	—	—	1,980[a]	—	—	2Q 2008 – 4Q 2010

This project will construct an approximately 335,000 gross square foot building with laboratories,

[a] The Physical Sciences Facility subproject will be funded primarily under 07-SC-05, a joint SC/NNSA funded project. The Office of Science does not request FY 2007 funds under this project; NNSA requests $7,500,000 in FY 2007. The FY 2006 appropriation provided $4,950,000 for project engineering and design and construction—$2,970,000 in 04-SC-01 and $1,980,000 in MEL-001.

offices and a Category 3 nuclear facility to accommodate a portion of the existing research capabilities being displaced as a result of the closure and cleanup of facilities in the Hanford 300 Area. This project is jointly funded by SC, NNSA, and the Department of Homeland Security. The allocation of costs among the three project sponsors was determined based upon the estimated net square footage of space required to perform research in support of each sponsor's mission needs. Sponsor shares of the Total Project Cost will be as follows: SC – 44%; NNSA – 31%; DHS – 25%, SC is not requesting constructions funds in FY 2007.

The subproject is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2006.........	1,980	TBD	—	TBD	—	TBD

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—4Q FY 2004
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2006
- External Independent Review Final Report—1Q FY 2007
- Critical Decision-2: Approve Performance Baseline—2Q FY 2007
- Critical Decision-3: Approve Start of Construction—1Q FY 2008
- Critical Decision-4A: Approve Start of Operations—4Q FY 2010
- Critical Decision–4BApprove Project Closeout—2QFY 2011

Environment, Safety and Health Projects:

g. Subproject 36 – Safety and Operational Reliability Improvements (SLAC)

TEC	Prev.	FY 2005	FY 2006	FY 2007	Outyear	Construction Start/ Completion Dates
15,600	1,988[a]	2,528[b]	5,314	5,770	—	4Q 2005 – 1Q 2008

This subproject has two components:

- Underground Utility Upgrades – this component will replace deteriorated sections of hot water, chilled water, cooling tower water, storm drainage, sanitary sewer lines, natural gas, and fire protection. These upgrades are critical to the operation of the linear accelerator and the B-Factory rings which produce the essential collisions needed for the Parity Violation studies (one of the pillars of the current US High Energy Physics program also carried out competitively at KEK in Japan). There have been several pipe failures over the last several years and the failure rate is expected to increase in these 35 year-old systems as they continue to age. When the pipes fail, research is slowed or halted until repairs are completed.

[a] Title I and Title II Design funding of $1,988,000 provided under PED Project No. 04-SC-001.
[b] Conference Report language redirected $4,500,000 from this subproject to the High Energy Physics (HEP) research program at SLAC.

- Seismic Upgrades – this component will install seismic upgrades necessary to bring various building structures into compliance with the seismic standards of the Uniform Building Code. The seismic hazard in the Bay Area is high. 12 facilities, i.e., those that will minimize the time required for the Laboratory to recover from an earthquake, will be retrofitted for a total of approximately 180,000 sq. ft.

  Payback is 11.2 years for the entire subproject.

The project is being conducted in accordance with the project management requirements in DOE Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2005........	15,600	100	—	15,700	—	15,700
FY 2006........	15,600	100	—	15,700	—	15,700
FY 2007........	15,600	100	—	15,700	—	15,700

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—2Q FY 2002
- Critical Decision-1: Approve Preliminary Baseline Range—1Q FY 2004
- External Independent Review Final Report—2Q FY 2006
- Critical Decision-2: Approve Performance Baseline—2Q FY 2006
- Critical Decision-3: Approve Start of Construction—4Q FY 2006
- Critical Decision-4: Approve Start of Operations—4Q FY 2009

h. Subproject 47 – Seismic Safety Upgrade of Buildings, Phase I (LBNL)

TEC	Prior years	FY 2005	FY 2006	FY 2007	Outyears	Construction Start/ Completion Dates
17,000	—	—	—	7,500[a]	9,500	3Q 2008 – 1Q 2011

The proposed Seismic and Structural Safety Upgrades of Buildings, Phase I, project will correct existing structural deficiencies in LBNL Buildings 50 and 74, enhancing the safety of over 600 occupants of the seismically deficient buildings. Each of these buildings has been assigned a "Poor" seismic performance rating per the University of California Seismic Safety rating system. A "Poor" seismic performance rating applies to buildings and other structures whose performance during a major seismic disturbance is anticipated to result in significant structural and non-structural damage and/or falling hazards that would represent appreciable life safety hazards. Proposed upgrades vary by building and include: column reinforcement, new tube bracing, connection and anchorage upgrades, reinforcing interior shear walls, supplemental vertical supports, gap enlargement between structures, new footings, and upgrades to structural exterior walls.

The subproject is being conducted in accordance with the project management requirements in DOE

[a] Title I and Title II design funding of $2,500,000 is provided under PED project no. 07-SC-0401.

Order 413.3, Program and Project Management for the Acquisition of Capital Assets.

Baseline and Validation Status

(dollars in thousands)

	TEC	OPC, Except D&D Costs	Offsetting D&D Costs	Total Project Costs	Validated Performance Baseline	Preliminary Estimate
FY 2007........	17,000	325	—	17,325	—	17,325

Compliance with Project Management Order

- Critical Decision-0: Approve Mission Need—3Q FY 2005
- Critical Decision-1: Approve Preliminary Baseline Range—4Q FY 2006
- External Independent Review Final Report—4Q FY 2007
- Critical Decision-2: Approve Performance Baseline—1Q FY 2008
- Critical Decision-3: Approve Start of Construction—3Q FY 2008
- Critical Decision-4: Approve Start of Operations—4Q FY 2010

5. Financial Schedule (dollars in thousands)

(dollars in thousands)

Fiscal Year	Appropriations	Obligations	Costs
Design/Construction by Fiscal Year			
Design			
Prior Years	4,756	4,756	2,265
FY 2005	313	313	1,185
FY 2006	—	—	1,619
FY 2007	8,908	8,908	5,485
FY 2008	—	—	3,423
Total, Design	13,977	13,977	13,977
Construction			
Prior Years	9,158	9,158	8,212
FY 2005	14,423	14,423	10,941
FY 2006	14,720	14,720	16,291
FY 2007	19,033	19,033	25,430
FY 2008	28,529	28,529	22,325
FY 2009	16,300	16,300	15,500
FY 2010	3,000	3,000	4,500
FY 2011	—	—	1,964
Total, Construction	105,163	105,163	105,163
Total TEC	119,140	119,140	119,140

6. Details of Project Cost Estimate

See subproject details.

7. Schedule of Project Costs

See subproject details.

8. Related Funding Requirements

See subproject details.

9. Required D&D Information

See subproject details.

10. Acquisition Approach

Construction and procurement will be accomplished by fixed-price contracts awarded on the basis of competitive bids.

Science Program Direction

Funding Profile by Subprogram

(dollars in thousands/whole FTEs)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Science Program Direction					
Program Direction	63,722	69,132	-1,027[ab]	68,105	75,045
Field Operations	90,309	91,593	-580[ab]	91,013	95,832
Total, Science Program Direction	154,031[c]	160,725	-1,607	159,118	170,877
Staffing					
Program Direction (FTEs)	315	349	-5[b]	344	369
Field Operations (FTEs)	606	650	+5[b]	655	645
Total, FTEs	921	999	—	999	1,014

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act"
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 SC Federal staff in headquarters responsible for managing, directing, administering, and supporting 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 our field complex responsible for program implementation (Site Offices located at SC laboratories) and for providing best-

[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006 as follows: Program Direction ($-691,000) and Field Operations ($-916,000).

[b] Reflects a reallocation of funding in accordance with H.Rpt. 109-275, the conference report for the Energy and Water Development Appropriations Act, 2006 as follows: Program Direction ($-336,000, -5 FTEs) and Field Operations ($+336,000, +5 FTEs).

[c] Total is reduced $1,237,000 for a rescission in accordance with P.L 108-447, the Consolidated Appropriations Act, 2005.

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.

As stated in the Departmental Strategic Plan, DOE's Strategic and General Goals will be accomplished not only through the efforts of the major program offices in the Department but with additional effort from offices which support the programs in carrying out the mission. SCPD performs critical functions which directly support the mission of the Department. These functions include providing and supporting a workforce capable of delivering 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.

Significant Program Shifts

- The FY 2007 SCPD budget request of $170,877,000 is an increase of $11,759,000 or 7.4%, over the SCPD FY 2006 appropriation and is less than 4.5% of the total Office of Science FY 2007 budget request of $4,101,710,000. $3,801,000 of the increase is related to salary, benefit and associated support costs for 25 additional full time equivalents (FTEs) in support of the Science Headquarters Program Offices who have direct responsibility for managing, directing, administering, and supporting the broad spectrum of SC scientific disciplines. Part of the increase ($5,042,000) is for payroll costs across the SC complex including a 2.2% payraise in January 2007, increased cap for SES basic pay, and other pay related costs such as the government's contributions for employee health insurance and Federal Employees' Retirement System (FERS). Part of the increase ($1,516,000) provides for escalation of non-pay categories, such as travel, training, and contracts; and increased e-Gov assessments and other fixed operating requirements across the SC complex. Finally, $1,400,000 of the increase is for requirements not requested in previous SCPD budget requests which include travel expenses of SC Advisory Committee members and requirements related to Appendix A of OMB Circular A-123, Management's Responsibility for Internal Control.
- The Office of Science has been officially reorganized under the OneSC structure. Phase 1 of the reorganization was effective March 20, 2005. The OneSC reorganization enhances organizational and functional alignment and reporting relationships through the reduction of layers of management, streamlines decision-making processes, and clarifies lines of authority. A clear set of integrated roles, responsibilities, authorities, and accountabilities encompass the headquarters organization, Site Offices, and the ISC.
- Phase 2 of OneSC involves human capital and organizational needs analyses and reengineering of SC business and management operations and processes. During Phase 2, the OneSC restructuring will be fully implemented. SC business practices and processes will be optimized to remove unnecessary work and support enhanced stewardship and oversight of SC's laboratories. This effort embraces the changes envisioned by the President's Management Agenda to manage government programs more efficiently and effectively.
- Attrition, retraining, reassignments, and workforce management incentives will be utilized to manage changes in staffing levels or skill mix needs resulting from Phase 2 activities. No downgrades, involuntary geographical transfers, separations, or reductions-in-force are planned or expected.
- DOE first launched its competitive sourcing program in March 2002. As a result of the A-76 competition for financial services, the OR Financial Service Center, funded within the SCPD budget, provides payment services for the entire, nation-wide DOE complex.

- In 2004, the Department's Competitive Sourcing Executive Steering Group approved a competitive sourcing study involving 684 positions, including 121 positions funded by SC, which perform Environmental Engineering Services functions such as environmental technical review, evaluation, and associated project and program work. Impact of this study on SC positions will not be known until the study has been completed, currently planned for March 2006.
- After completion of competitive sourcing feasibility reviews, the Department has determined that the SC business areas of Management Support to R&D; Non-Manufacturing Operations; and R&D, Test and Evaluation are not suitable for A-76 competition at this time.
- The Department has completed an A-76 competitive sourcing study of its Human Resources (HR) Training Services functions. The Most Efficient Organization (MEO) won the competition and plans to reorganize and centralize Departmental training services across the country. As a result of anticipated efficiencies, Department savings of $34,000,000 are estimated over 5 years. In FY 2007, SC funding associated with these functions ($628,000) will be transferred to the Department Administration appropriation to provide for the operation of the new consolidated training services organization.
- 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 including cyber security. Specific SC employee assignments and impacts will not be known until management and HR staffs have applied all relevant law, regulations, and procedures.

Program Direction

Funding Profile by Category

	(dollars in thousands/whole FTEs)		
	FY 2005	FY 2006	FY 2007
Headquarters			
Salaries and Benefits	42,732	46,304	50,942
Travel	1,699	1,902	2,814
Support Services	11,634	10,857	11,141
Other Related Expenses	7,657	9,042	10,148
Total, Headquarters	63,722	68,105	75,045
Full Time Equivalents	315	344	369

Mission

The Program Direction subprogram funds all of the SC Federal staff in headquarters 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 disciplines include the 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's mission is to advance science and sustain technological creativity by making R&D findings available and useful to DOE researchers and the American people. 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. On an annual basis, there are over 15 million downloads or "views" of R&D findings on these and other OSTI systems. OSTI also developed and hosts the interagency e-Government system Science.gov, which uses breakthrough technology for simultaneously searching across 47 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 2005	FY 2006	FY 2007
Salaries and Benefits	**42,732**	**46,304**	**50,942**

The FY 2007 request supports 369 FTEs at Headquarters and addresses the highest priority staffing concerns identified by recent Committee of Visitors (COV) reports, and includes funding for workforce management incentives to corporately maintain a technically skilled and highly motivated workforce.

In addition, the FY 2007 request assumes an increased pay cap for Senior Executive Service (SES) basic pay and a 2.2% pay raise in January 2007.

Travel	**1,699**	**1,902**	**2,814**

Travel includes all costs of transportation of persons, subsistence of travelers, and incidental travel expenses in accordance with Federal travel regulations; and enables headquarters 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. In FY 2006, Advisory Committee membership travel will be funded with prior year carryover balances. Each SC Advisory Committee operates in accordance with the Federal Advisory Committee Act (FACA), Public Law 92-463, H.R. 4383; (October 6, 1972) and all applicable FACA Amendments, Federal Regulations and Executive Orders.

In addition, the travel funding request for the headquarters Program Offices addresses travel deficiencies identified by recent COV reports.

Support Services	**11,634**	**10,857**	**11,141**

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 IT support is provided to include the following:
(1) maintenance and operation of SC-Headquarters Information Management systems and infrastructure; (2) SC-corporate Enterprise Architecture, Capital Planning Investment Control, and cyber security management; (3) completion of the Development, Modernization, Enhancement (DME) portion of the electronic Portfolio Management Application, which will have the capability to receive non-R&D electronic laboratory proposals in addition to R&D electronic laboratory proposals; and (4) accessibility of DOE's multi-billion dollar R&D program through the e-Government information systems administered by OSTI.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

Support is provided for the Congressionally-mandated competition of the Argonne and Ames laboratory contracts; and competition of the Fermi National Accelerator Laboratory contract 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.

Capital Equipment funding is included for a Storage Area Network at OSTI ($127,000).

Other Related Expenses	**7,657**	**9,042**	**10,148**

The request provides support through the Working Capital Fund (WCF) to headquarters for office space, utilities, building/equipment maintenance, mail services, LAN connections, supplies, and other services and equipment. Also provides for communications, utilities building/equipment maintenance, supplies, equipment, and other services at OSTI. Includes SC's funding contribution for operation and maintenance of the Standard Accounting and Reporting System and OMB Circular A-123 requirements; IT project management training; and e-Government initiative fees for E-Travel, Business Gateway, Integrated Acquisition Environment, Geospatial One-Stop, Recruitment One-Stop, Enterprise HR Initiative, Lines of Business, and Grants.gov.

Total, Program Direction	**63,722**	**68,105**	**75,045**

Explanation of Funding Changes

	FY 2006 vs. FY 2007 ($000)
Salaries and Benefits	
Supports 369 FTEs, an increase of 25 FTEs over FY 2006; assumes a 2.2% pay raise for 2007; and increased cap for SES basic pay.	+4,638
Travel	
Increase incorporates non-pay inflation of 2.2% and supports Advisory Committee members' travel expenses, which are funded in FY 2006 from prior year carryover balances.	+912
Support Services	
Increase is primarily related to non-pay escalation of 2.2% for support service contracts. This increase is partially offset by a transfer to the Departmental Administration appropriation to provide for the operation of a new consolidated Departmental training services organization ($-188,000).	+284

	FY 2006 vs. FY 2007 ($000)
Other Related Expenses	
Increase is primarily related to SC's contribution to the WCF for OMB Circular A-123 requirements, increased e-Gov assessments and supplies, materials and other services at Headquarters in support of an increased workforce.	+1,106
Total Funding Change, Program Direction	**+6,940**

Support Services by Category

(dollars in thousands)

	FY 2005	FY 2006	FY 2007	$ Change	% Change
Technical Support					
Feasibility of Design Considerations	130	130	—	-130	-100.0%
Development of Specifications	350	290	304	+14	+4.8%
System Definition	160	140	250	+110	+78.6%
System Review and Reliability Analyses	475	485	627	+142	+29.3%
Trade-off Analyses	55	35	—	-35	-100.0%
Test and Evaluation	156	169	—	-169	-100.0%
Total, Technical Support	1,326	1,249	1,181	-68	-5.4%
Management Support					
Automated Data Processing	7,439	7,175	6,710	-465	-6.5%
Training and Education	287	290	319	+29	+10.0%
Reports and Analyses Management and General Administrative Services	2,582	2,143	2,931	+788	+36.8%
Total, Management Support	10,308	9,608	9,960	+352	+3.7%
Total, Support Services	11,634	10,857	11,141	+284	+2.6%

Other Related Expenses by Category

	(dollars in thousands)				
	FY 2005	FY 2006	FY 2007	$ Change	% Change
Other Related Expenses					
Communications, Utilities, Miscellaneous	354	368	375	+7	+1.9%
Printing and Reproduction	2	2	2	—	—
Other Services	2,206	1,302	1,554	+252	+19.4%
Operation & Maintenance of Equipment	88	910	912	+2	+0.2%
Supplies and Materials	64	260	379	+119	+45.8%
Equipment	546	125	127	+2	+1.6%
Working Capital Fund	4,397	6,075	6,799	+724	+11.9%
Total, Other Related Expenses	7,657	9,042	10,148	+1,106	+12.2%

Field Operations

Funding Profile by Category

	(dollars in thousands/whole FTEs)		
	FY 2005	FY 2006	FY 2007
Chicago Office (CH)			
Salaries and Benefits	20,086	20,628	22,008
Travel	448	200	320
Support Services	1,392	1,466	1,867
Other Related Expenses	3,380	2,425	1,967
Total, CH	25,306	24,719	26,162
Full Time Equivalents, CH	184	193	192
Oak Ridge Office (OR)			
Salaries and Benefits	28,202	28,720	30,061
Travel	430	430	500
Support Services	6,698	6,213	6,080
Other Related Expenses	7,092	7,171	7,611
Total, OR	42,422	42,534	44,252
Full Time Equivalents, OR	278	298	289
Ames Site Office (AMSO)			
Salaries and Benefits	400	412	446
Travel	15	15	15
Support Services	19	23	21
Other Related Expenses	36	3	38
Total, AMSO	470	453	520
Full Time Equivalents, AMSO	3	3	3
Argonne Site Office (ASO)			
Salaries and Benefits	2,886	3,127	3,221
Travel	43	40	40
Support Services	175	202	230
Other Related Expenses	309	308	322
Total, ASO	3,413	3,677	3,813
Full Time Equivalents, ASO	23	25	25

	FY 2005	FY 2006	FY 2007
	(dollars in thousands/whole FTEs)		
Berkeley Site Office (BSO)			
Salaries and Benefits	2,648	3,121	3,601
Travel	47	96	98
Support Services	329	182	224
Other Related Expenses	337	276	318
Total, BSO	3,361	3,675	4,241
Full Time Equivalents, BSO	20	25	25
Brookhaven Site Office (BHSO)			
Salaries and Benefits	2,612	3,062	3,215
Travel	47	50	45
Support Services	358	238	191
Other Related Expenses	250	187	192
Total, BHSO	3,267	3,537	3,643
Full Time Equivalents, BHSO	20	24	24
Fermi Site Office (FSO)			
Salaries and Benefits	1,931	1,977	2,074
Travel	30	40	41
Support Services	105	125	125
Other Related Expenses	119	93	106
Total, FSO	2,185	2,235	2,346
Full Time Equivalents, FSO	15	15	15
Pacific Northwest Site Office (PNSO)			
Salaries and Benefits	3,996	4,345	4,438
Travel	124	93	95
Support Services	140	136	135
Other Related Expenses	1,017	864	885
Total, PNSO	5,277	5,438	5,553
Full Time Equivalents, PNSO	31	36	36
Princeton Site Office (PSO)			
Salaries and Benefits	1,453	1,544	1,616
Travel	28	15	10
Support Services	1	10	—
Other Related Expenses	72	49	42
Total, PSO	1,554	1,618	1,668
Full Time Equivalents, PSO	12	12	12

	FY 2005	FY 2006	FY 2007
	(dollars in thousands/whole FTEs)		
Stanford Site Office (SSO)			
Salaries and Benefits	1,343	1,293	1,703
Travel	80	52	53
Support Services	119	230	264
Other Related Expenses	105	95	114
Total, SSO	1,647	1,670	2,134
Full Time Equivalents, SSO	10	13	13
Thomas Jefferson Site Office (TJSO)			
Salaries and Benefits	1,205	1,314	1,365
Travel	61	67	47
Support Services	76	19	55
Other Related Expenses	65	57	33
Total, TJSO	1,407	1,457	1,500
Full Time Equivalents, TJSO	10	11	11
Total Field Operations			
Salaries and Benefits	66,762	69,543	73,748
Travel	1,353	1,098	1,264
Support Services	9,412	8,844	9,192
Other Related Expenses	12,782	11,528	11,628
Total, Field Operations	90,309	91,013	95,832
Full Time Equivalents, Field Operations	606	655	645

Mission

The Field Operations subprogram is the centralized funding source for the SC Field Federal workforce. Responsibilities include the ISC (comprised by the CH and OR 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.

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 and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, and information systems development and support.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as IT maintenance, administrative support, mail services, document classification, personnel security clearances, emergency management, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, and facility and ground maintenance are also included. Services provided through the Department's WCF include online training in the Corporate HR Information System and payroll processing. 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 2005	FY 2006	FY 2007
Salaries and Benefits	**66,762**	**69,543**	**73,748**

The FY 2007 request supports 645 FTEs in the SC field complex. The reduction of 10 FTEs across the field complex will be accomplished through attrition and workforce management incentives. The FY 2007 salary request assumes a 2.2% pay raise in January 2007 and increased cap for SES basic pay.

Travel	**1,353**	**1,098**	**1,264**

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; i.e., 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 and/or certification, etc. The FY 2007 request incorporates the non-pay inflation factor of 2.2%.

Support Services	**9,412**	**8,844**	**9,192**

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	**12,782**	**11,528**	**11,628**

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 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	**90,309**	**91,013**	**95,832**

Explanation of Funding Changes

	FY 2006 vs. FY 2007 ($000)
Salaries and Benefits	
Supports 645 FTEs and assumes a 2.2% pay raise for 2007 and increased pay cap for SES basic pay. Objective is to reduce level of FTEs (-10) utilizing attrition and workforce management incentives. In some areas, FTEs have been increased in order to specifically address skill mix needs; 1) CH budget/acquisition workload from NNSA closure of Oakland Operations Center; 2) OneSC Deputy Managers at BSO/SSO; and 3) additional SSO Safety Specialist.	+4,205
Travel	
Increase supports Federal workforce and incorporates non-pay inflation of 2.2%.	+166
Support Services	
The funding increase in FY 2007 is the result of 1) increases to the CH IT "seat" or workstation charge resulting from a diminishing non-SC population; particularly the Office of Environmental Management presence; 2) conversion of SSO administrative support from federal to contract services; and 3) incorporating non-pay inflation of 2.2%. In addition, a transfer to the Department Administration appropriation provides for the operation of a new consolidated Departmental training services organization ($-390,000).	+348
Other Related Expenses	
Increase supports the WCF and escalation. Offsetting reductions include 1) Other Services and Supplies and Materials; and 2) funding transfer to the Departmental Administration appropriation for the consolidation of the Department's HR Training Services functions ($-50,000).	+100
Total Funding Change, Field Operations	**+4,819**

Support Services by Category

(dollars in thousands)

	FY 2005	FY 2006	FY 2007	$ Change	% Change
Technical Support					
Development of Specifications	—	18	—	-18	-100.0%
Management Support					
Directives Management Studies	309	318	328	+10	+3.1%
Automated Data Processing	3,070	4,606	3,771	-835	-18.1%
Preparation of Program Plans	386	340	350	+10	+2.9%
Training and Education	1,012	991	869	-122	-12.3%
Analyses of DOE Management Processes	31	—	—	—	—
Reports and Analyses Management and General Administrative Services	4,604	2,571	3,874	+1,303	+50.7%
Total, Management Support	9,412	8,826	9,192	+366	+4.1%
Total, Support Services	9,412	8,844	9,192	+348	+3.9%

Other Related Expenses by Category

(dollars in thousands)

	FY 2005	FY 2006	FY 2007	$ Change	% Change
Other Related Expenses					
Rent to GSA.	883	915	947	+32	+3.5%
Rent to Others	1,509	1,881	1,489	-392	-20.8%
Communications, Utilities, Miscellaneous	3,218	2,042	2,565	+523	+25.6%
Printing and Reproduction	108	109	121	+12	+11.0%
Other Services	2,972	2,645	2,221	-424	-16.0%
Purchases from Government Accounts	166	—	—	—	—
Operation and Maintenance of Equipment	2,207	1,743	2,593	+850	+48.8%
Supplies and Materials	885	1,430	512	-918	-64.2%
Equipment	534	319	610	+291	+91.2%
Working Capital Fund	300	444	570	+126	+28.4%
Total, Other Related Expenses	12,782	11,528	11,628	+100	+0.9%

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Capital Equipment	233	272	127

Workforce Development for Teachers and Scientists

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Workforce Development for Teachers and Scientists					
Undergraduate Research Internships	3,338	2,963	—	2,963	3,170
Graduate/Faculty Fellowships	3,049	3,090	-72[a]	3,018	6,722
Pre-College Activities	1,212	1,139	—	1,139	1,060
Total, Workforce Development for Teachers and Scientists	7,599[b]	7,192	-72	7,120	10,952

Public Law Authorizations:

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

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

The Omnibus Energy Legislation: Sec. 995. Educational Programs in Science and Mathematics amends the Public Law 101-510, "DOE Science Education Enhancement Act"

Public Law 109-58, "Energy Policy Act 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 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

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.

[b] Total is reduced $61,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.

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.

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, provides 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 Laboratory Science Teacher Professional Development (LSTPD) activity is a 3-year commitment experience for K-14 teachers and faculty and was originally designed to add a cohort of about 50 teachers each year. FY 2007 represents the fourth year of this program. The first cohort of 62 teachers began in FY 2004, the second cohort of approximately 28 teachers began in FY 2005, and the third cohort of 18 teachers will begin in FY 2006.

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 LSTPD 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.

The FY 2007 request includes a significant increase in funding for LSTPD which will expand the fourth cohort to about 300 teachers. The $5,645,000 requested in FY 2007 for LSTPD will be used to provide K-14 teachers, with an emphasis on middle school teachers, the content knowledge and leadership skills that will transform them into agents of change and lead to not only institutional reform in the STEM education system but also improved student achievement.

Supporting Information

As documented by a July 2001 DOE Inspector General Report, the Department faces a critical and immediate shortage of scientific and technical staff sufficient to meet its mission requirements. In the report on "Recruitment and Retention of Scientific and Technical Personnel," (DOE/IG-0512, July 2001, http://www.ig.doe.gov/pdf/ig-0512.pdf), GAO reported that, "the Department was unable to recruit and retain critical scientific and technical staff in a manner sufficient to meet identified missions. Based on their analysis of attrition and hiring since 1999, GAO determined that as of January 2001, the Department faced an immediate need for as many as 577 scientific and technical specialists. Furthermore, if this trend continues, the Department could face a shortage of nearly 40% in these classifications within five years." WDTS is addressing this shortfall by managing its current programs to ensure that they align with the mission of SC and the national laboratories.

According to the National Center for Education Statistics, between 2000 and 2008, enrollment in public high schools is expected to increase by 4% while more than 25% of teachers are at least 50 years old and the median age is 44. This translates to 150,000 to 250,000 openings for teachers in the nation's elementary and secondary schools over the next ten years.

The WDTS program provides a grade school through graduate school set of opportunities that are unified under the common belief that DOE national laboratories can provide unique training and professional development research experiences that enhance the technical skills and content knowledge in science and mathematics of teachers and students, strengthen their investigative expertise, inspire commitments to science and engineering careers, and build a link between the resources of the national laboratories and the science education community. These opportunities are complimentary to the efforts of other federal agencies, such as the NSF and the Department of Education, and provide support that might otherwise be unavailable to these agencies' programs and students they serve.

Undergraduate Internships

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Undergraduate Research Internships			
Science Undergraduate Laboratory Internship	2,560	2,377	2,645
Community College Institute of Science and Technology	401	328	311
Pre-Service Teachers	377	258	214
Total, Undergraduate Research Internships	3,338	2,963	3,170

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 performs 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 2005 Accomplishments

- To document and evaluate the quality of the research experience and the collaboration of the intern with their mentor researcher, WDTS publishes the "Journal of Undergraduate Research" containing full-length peer-reviewed research papers and abstracts of students' research in the activity. All scientific research abstracts are graded to measure the quality of the students' ability to prepare scientific manuscripts. A fifth edition was published in 2005, with 15 full-length papers and 653 abstracts.
- In 2005, more than 96% of all students in undergraduate research internships submitted abstracts and research papers.
- The students who published full-length papers presented their work at a poster session at the American Association for the Advancement of Science (AAAS) national meeting in Washington, DC in February 2005. Of the 15 students who presented their work, 5 received awards from the AAAS judges.
- The "Undergraduate Research Internships Program Guidebook" was revised in 2005 to specify outcomes for the Faculty and Student Teams (FaST) undergraduate faculty and updated laboratory contact information. It is an invaluable tool for both students and laboratory research mentors as it describes the responsibilities, requirements, and outcomes that are associated with a successful internship. The guidebook contains formats and instructions for the written requirements, including scientific abstract, research paper, oral presentation, poster, and instructions for an education module for the PST activity.
- There was an increase in National Science Foundation (NSF) funded participants at national laboratories in the undergraduate internship programs and the FaST. For summer 2005, there were a total of 68 NSF funded students that participated on FaST teams selected by 11 laboratories. These participants were eligible for supplemental funding from the NSF to pay for their stipends and travel.
- WDTS staff designed and published "Building Toward a Better Future," a college planning guide for students and families in both English and Spanish versions. This guide provides useful information and tips on preparing for college and becoming a successful applicant for college admission and financial aid. Tips for parents and students begin at the elementary school level.
- 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 surveys.

- CCI is open to students from all community colleges. In the summer of 2005, 80 community college students, including NSF funded participants, attended a 10-week mentor-intensive scientific research experience at several DOE national laboratories. About 30% of the participating students came from underrepresented 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.
- 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.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Science Undergraduate Laboratory Internship (SULI) ...	**2,560**	**2,377**	**2,645**

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 students' 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 career 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 outside evaluation. An undergraduate student journal is produced annually that publishes peer-reviewed research papers and all abstracts of students in the 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 2005, with DOE, NSF and other leveraged support, 32 students participated in the spring semester program, 395 students participated in the summer, and 22 students in the fall semester program. The DOE contribution will support an estimated 300 students in FY 2006 and 355 students in FY 2007.

Community College Institute of Science and Technology (CCI)	**401**	**328**	**311**

This activity is designed to address shortages, particularly at the technician and paraprofessional levels, and will help develop the workforce needed to continue building the DOE's capacity in critical areas for the next century. Since community colleges account for over 40% of the entire Nation's undergraduate

	(dollars in thousands)	
FY 2005	FY 2006	FY 2007

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 the 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 students' 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 collaborative effort with DOE, its national laboratories, the American Association of Community Colleges, 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 2005, 68 students directly participated in this internship, with an estimated 54 students participating in FY 2006 and an estimated 50 students participating in FY 2007.

Pre-Service Teachers (PST)	**377**	**258**	**214**

The 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 SC 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 also may produce a research paper or 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, the Pre-Service Teachers (PST) activity was reduced to 9 National Laboratories with 33 participating students, compared to 10 National Laboratories with 52 students in FY 2005. In FY 2007, the program is further reduced to 7 National Laboratories and about 29 students participating in order to direct funds to higher priority activities.

Total, Undergraduate Research Internships	**3,338**	**2,963**	**3,170**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Science Undergraduate Laboratory Internship	
The number of students participating in SULI increases by 55 students from 300 students in FY 2006 to 355 students in FY 2007.	+268
Community College Institute of Science and Technology	
The number of students participating in CCI decreases by 4 students, from 54 students in FY 2006 to 50 students in FY 2007.	-17
Pre-Service Teachers	
The number of students participating in PST decreases by 4 students, from 33 students in FY 2006 to 29 students in FY 2007.	-44
Total Funding Change, Undergraduate Research Internships	**+207**

Graduate/Faculty Fellowships

Funding Schedule by Activity

(dollars in thousands)

	FY 2005	FY 2006	FY 2007
Graduate/Faculty Fellowships			
Laboratory Science Teacher Professional Development	1,494	1,840	5,645
Faculty and Student Teams	365	260	243
Albert Einstein Distinguished Educator Fellowship	700	700	650
Energy Related Laboratory Equipment	90	90	90
Faculty Sabbatical Fellowship	400	128	94
Total, Graduate/Faculty Fellowships	3,049	3,018	6,722

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 needs 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 five functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

Three activities at the graduate level each provide different benefits. The Laboratory Science Teacher Professional Development (LSTPD) will establish long-term relationships between K-14 teachers and the national laboratories. 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) and Faculty Sabbatical programs will benefit the individual faculty, their students and their respective institutions by giving them the training needed to successfully compete for federal science grants.

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 Laboratory Science Teacher Professional Development (LSTPD) program is targeted at the nation's teachers. The primary goal of the LSTPD program 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."

The LSTPD program provides K-14 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. 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 underrepresented 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 SULI or CCI funds. Over a ten-week summer visit to the laboratory, the faculty are 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. This activity is in compliance with the Albert Einstein Distinguished Educator Act of 1994, which gives the DOE responsibility for administering the 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.

The Faculty Sabbatical program is an extension of the successful FaST program and provides research sabbaticals for faculty members from Minority Serving Institutions (MSI) to collaborate with resident scientists at national laboratories for up to one year on research projects specific to the visiting professors' areas of investigation and the courses they teach. It is the extended stay at the laboratory, along with the concentrated support of the mentor scientist that develops the faculty members' scientific expertise as a teacher, the research capacity of their home institution, and supports their efforts to apply for and receive grants from SC and other granting institutions.

FY 2005 Accomplishments

- The LSTPD program continued at seven national laboratories for 90 teachers. An external evaluation team provided an evaluation report on the first cohort, and found that the LSTPD Program in its pilot year was successful in improving teacher content knowledge and leadership skills. The report indicated that each laboratory had shown significant merit in helping teachers gain new knowledge in a broad range of science. In particular, two national laboratories (Pacific Northwest National Laboratory and Lawrence Berkeley National Laboratory) showed outstanding achievement in meeting the LSTPD program's systemic goals 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 and regional teaching communities. These two national laboratories will be used as models for other laboratories in their LSTPD programs.
- FaST is aimed at helping faculty from colleges who are in the lower 50^{th} percentile of federal research funding and those institutions serving populations, including women and minorities, underrepresented in STEM fields. In 2005, five SC laboratories–Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, and Pacific Northwest National Laboratories–placed 42 hosted Faculty and Student Teams, with 35 of those being partially supported by the NSF. Since the program began about 28 FaST faculty have submitted grant proposals to federal institutions/agencies. Some of the funded proposals include: (1) Jackson State University (MS)—Use of both two-dimensional gel electrophoresis; (2) Laney Community College (CA) & LBNL—Environmental Control Technology Education for Advanced Building Operation and Management; and (3) Southern University (LA)—X-ray Detector Lab Development. In FY 2004–05 alone, six faculty participating at the Brookhaven National Laboratory submitted 17 grant proposals, with 6 being funded, and 5 still pending notification. These grants have been a direct product of the FaST experiences. Three Faculty and Student Teams have received peer-reviewed publications in the Journal of Undergraduate Research.
- By leveraging resources and collaborating with other service agencies, the Albert Einstein Distinguished Educator Fellowship activity for FY 2005–2006 placed 17 outstanding K-12 science, math, and technology teachers: 4 in Congressional offices, 1 at the DOE, 2 at the National Aeronautics and Space Administration (NASA), 5 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). This is the largest representation of agencies and highest number of Fellows placed in any year since the inception of the program. By continuing to collaborate with other federal agencies, we hope to be able to place five more fellows in FY 2006 than previous years.
- Two faculty members impacted by Hurricane Katrina were placed at DOE national laboratories in Faculty Sabbatical appointments.

professional developmental needs and the follow-on interaction between the teachers and the national laboratories.

The request for FY 2007 would expand the Laboratory Science Teacher Professional Development program to a major national program supporting 300 teachers, and especially targeting middle school teachers, to participate in mentored research opportunities at the national laboratories. This provides the opportunity to make a real impact in attracting students to study and ultimately work in STEM careers. By incorporating STEM teachers into the scientific community of the national laboratories, they are provided with the tools they need to improve their classroom and overall professional performance, their leadership abilities in the STEM educational community, and most importantly, their student's achievement.

Faculty and Student Teams (FaST)...............................	**365**	**260**	**243**

Faculty 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 colleges and universities with limited prior research capabilities and those institutions serving women, minorities, 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 the first year (FY 2001) of this program, there was one FaST team. In part because of increasing support from the NSF, there were 6 teams in FY 2002, 23 teams in FY 2003, 31 teams in FY 2004, and 42 in FY 2005. In FY 2006, with similar support from NSF, it is projected that there will be about 34 FaST teams, with 10 fully funded by DOE. With funding reduced overall for WDTS in FY 2006, the FY 2006 DOE contribution for FaST is also reduced. The FY 2007 request will reduce the number of teams participating in order to focus funding on higher priority activities. 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....	**700**	**700**	**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 2005, with the organizational support of DOE, other federal agencies, including the NSF, NASA, NOAA, NIH, and NIST, were able to place 17 teachers as Einstein Fellows. The FY 2007 request will directly support 4 fellows in Congress and 1 at DOE. It will also allow for the continued organizational support for the placement of additional fellows in other federal agencies.

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Energy Related Laboratory Equipment (ERLE)	**90**	**90**	**90**

The ERLE grant activity provides excess equipment to 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 at 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, and the receiving institution pays for shipping costs.

Faculty Sabbatical Fellowship......................................	**400**	**128**	**94**

The Faculty Sabbatical provides support for up to a year of direct research with resident national laboratory scientists on research projects specific to their areas of investigation and courses they teach. The Faculty Sabbatical activity was originally designed for MSI faculty to work with a national laboratory scientist on a well funded, focused research project of the faculty member's choice to develop the faculty members' scientific expertise. Many of the 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. Initial planned funding in FY 2005 was for 12 faculty members, but due to a lack of response, only 10 were placed, and of this number, 2 were placed at the last minute because of the Hurricane Katrina disaster. Because of this experience and the overwhelming success of the FaST program, support is reduced in FY 2006 to 4 and further reduced to 2 Faculty Sabbatical appointments in FY 2007.

Total, Graduate/Faculty Fellowships............................	**3,049**	**3,018**	**6,722**

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Laboratory Science Teacher Professional Development	
The number of teachers participating in LSTPD increases by 192 in FY 2007, from 108 in FY 2006 to 300 in FY 2007, reflecting an increased effort to train middle school teachers at national laboratories.	+3,805
Faculty and Student Teams	
The number of SC funded FaST teams is reduced by 1 (from 10 in FY 2006 to 9 in FY 2007) but continued coordination with NSF is likely to result in a comparable number of teams as supported in FY 2006.	-17

	FY 2007 vs. FY 2006 ($000)
Albert Einstein Distinguished Educator Fellowship	
The number of Albert Einstein participants receiving direct DOE support in FY 2007 remains at 5, the same as FY 2005 and FY 2006. Continued collaboration with other federal agencies should result in an equal or greater number of Einstein Fellows (12) supported in FY 2006 and FY 2007.	-50
Faculty Sabbatical Fellowship	
The number of Faculty Sabbaticals for faculty members from MSIs is reduced by 2 (from 4 in FY 2006 to 2 in FY 2007).	-34
Total Funding Change, Graduate/Faculty Fellowships	**+3,704**

Pre-College Activities

Funding Schedule by Activity

	FY 2005	FY 2006	FY 2007
	(dollars in thousands)		
Pre-College Activities			
National Science Bowl®	937	799	718
Middle School Science Bowl	275	340	342
Total, Pre-College Activities	1,212	1,139	1,060

Description

Beyond providing students an opportunity to interact with the scientific community, an additional goal of the middle and high school Science Bowl 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. It also provides a critical component of "modeling" to inspire students' interest in science.

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 where 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 2005 Accomplishments

- 2005 marked the 15th anniversary of the DOE's National Science Bowl® More than 12,000 high school students were hosted in the 63 regional science bowl events.
- The Middle School Science Bowl, initiated in FY 2002 with 8 teams, expanded to 24 regional teams in FY 2005. The national event was hosted by the National Renewable Energy Laboratory at the Colorado School of Mines in Golden, Colorado. The event has two main activities: 1) a science and mathematics academic question and answer forum; and 2) a hands-on activity sponsored by General Motors, where each team designs, builds, and races a scale-model hydrogen fuel cell car. Teachers attended a half day workshop in Physics and participated in many hands-on physics activities that they could in turn take back to their schools to enhance science lessons in their classrooms. Texas Instruments sponsored some of the awards for the winning teams.
- Students, coaches and coordinators evaluated the Middle School Science Bowl, an evaluation report was compiled and program improvements are being made based on the recommendations.
- Saturday morning science seminars were expanded in FY 2004 and continued in FY 2005 to include an entire day, at the National Science Bowl® weekend, introducing students to many contemporary issues and findings in contemporary scientific research. These seminars have featured world class scientists and Nobel laureates.
- National Science Bowl® awards expanded in FY 2005 to include a variety of academic awards to the top 16 teams and a Civility Award sponsored by IBM.
- In FY 2005, 18 of the 63 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. Nine of these teams raced in the stock category and the other 9 in the hill climb. Awards were presented to the top teams in this event.
- General Motors (GM) has been a major sponsor of both the middle and high school Science Bowls, particularly regarding the fuel cell activities, and has been pleased with the quality and quantity of student and teacher involvement.

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
National Science Bowl®	**937**	**799**	**718**

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. In 1991, DOE began the National Science Bowl® to encourage high school students from across the nation to excel in mathematics and science and to pursue careers in those fields. The National

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

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 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.

The number of regional events remains relatively constant from one year to the next. In FY 2007, support for the National Science Bowl is reduced by $81,000 below FY 2006 and $219,000 below FY 2005, which will result in the curtailment of the full day science seminars and workshops at the National Science Bowl weekend.

Middle School Science Bowl	**275**	**340**	**342**

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 will be 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.

In FY 2007, 28 teams, the same as the FY 2006, will attend and participate in the National event.

Total, Pre-College Activities	**1,212**	**1,139**	**1,060**

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Laboratory Science Teacher Professional Development (LSTPD)...	**1,494**	**1,840**	**5,645**

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.

Research in teacher professional development indicates that change takes place over an extended period of time and that multi-year professional development is required to make the necessary differences. Consequently, teachers make a 3-year commitment to the LSTPD, which began in FY 2004. Approximately 62 teachers in FY 2004, 90 teachers in FY 2005 (62 continuing from FY 2004 and 28 new), 108 teachers in FY 2006 (up to 90 continuing from FY 2004 and FY 2005) have or 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-14 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, travel, and housing expenses.

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 long-term impact of the program on student achievement. External evaluators submitted a report on the first program year. Success of this research experience relies on proper placement of each participant to match their

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
National Science Bowl®	
Support will be reduced for scientific seminars and workshops from a whole day to a half day for the students, but DOE will continue to provide funding for all teams to attend the National finals.	-81
Middle School Science Bowl	
A slight increase provides for minor increases in organizational costs	+2
Total Funding Change, Pre-College Activities	**-79**

Safeguards and Security

Funding Profile by Subprogram

(dollars in thousands)

	FY 2005 Current Appropriation	FY 2006 Original Appropriation	FY 2006 Adjustments	FY 2006 Current Appropriation	FY 2007 Request
Safeguards and Security					
Protective Forces	27,485	29,010	—	29,010	33,050
Security Systems	10,495	11,030	—	11,030	6,615
Information Security	3,403	3,331	—	3,331	3,331
Cyber Security	15,708	15,571	-156[a]	15,415	18,070
Personnel Security	4,961	5,777	-531[a]	5,246	5,725
Material Control and Accountability	2,363	2,385	—	2,385	2,341
Program Management	8,358	7,213	—	7,213	7,460
Subtotal, Safeguards and Security	72,773	74,317	-687	73,630	76,592
Less Security Charge for Reimbursable Work	-5,605	-5,605	—	-5,605	-5,605
Total, Safeguards and Security	67,168[b]	68,712	-687	68,025	70,987

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

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[a] Reflects a rescission in accordance with P.L. 109-148, the Emergency Supplemental Appropriations Act to Address Hurricanes in the Gulf of Mexico and Pandemic Influenza, 2006.
[b] Total is reduced by $542,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.

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, and 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 Office of Science is participating in a joint Cyber Security Assistance Team (CSAT) program with the Office of the Chief Information Officer and the Office of Security and Safety Performance Assurance to improve the Federal and laboratory cyber security posture. This program has established standardized templates and approaches for the laboratories, established a testing baseline, and identified vulnerabilities (gaps) that must be mitigated. In FY 2006, each site will have the initial assistance visit completed at a minimum. FY 2007 will be dedicated to the second and third visits. The gaps already identified from the site visits performed include securing wireless infrastructure, implementing standard configuration controls on all computing devices, implementing an enterprise asset management tool, as well as the need to test all management, operational and technical controls in accordance with the National Institute of Standards and Technology (NIST) SP800-53A "Recommended Security Controls for Federal Information Systems." Funding in FY 2007 is increased by $2,655,000 to begin to fill the significant gaps at the laboratories.

Personnel Security

The Personnel Security activity includes security clearance programs, employee security education, and visitor control. 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.

Significant Program Shifts

The FY 2007 request for Safeguards and Security includes full funding necessary to protect people and property at the 2003 Design Basis Threat (DBT) level. Security Systems decreases primarily due to funding provided in FY 2006 for 2003 DBT requirements at Oak Ridge National Laboratory for one time upgrades and improvements of entry points; in FY 2007, the focus and funding shifts to Protective Forces. Cyber Security increases in FY 2007 in response to a more dynamic threat situation and the promulgation of new NIST requirements which are statutorily required by the Federal Information Security Management Act (FISMA).

Detailed Justification

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Ames Laboratory	**505**	**507**	**570**

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation, and oversight in the areas of security systems, protective forces, personnel security, and material control and accountability. Increased funding is also included for cyber security activities in FY 2007. 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; the amount for FY 2007 is $26,000.

Argonne National Laboratory	**8,671**	**8,570**	**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. Other program activities include protective forces, security systems, material control and accountability, information security, and personnel security. Increased funding is also included for cyber security activities in FY 2007. These activities ensure that the facility, personnel, and assets remain safe from potential threats. Reimbursable work is included in the numbers above; the amount for FY 2007 is $388,000.

Brookhaven National Laboratory	**11,335**	**11,229**	**10,967**

The Brookhaven National Laboratory (BNL) Safeguards and Security program activities are focused on protective forces, physical security, material control and accountability, and cyber security. 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; the amount for FY 2007 is $806,000.

Fermi National Accelerator Laboratory	**3,015**	**2,893**	**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, and toward continuing the security systems, and material control and accountability programs to accurately account

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007

for and protect the facility's special nuclear materials. Increased funding is also included for cyber security activities in FY 2007.

Lawrence Berkeley National Laboratory	**5,733**	**4,723**	**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, personnel security, and material control and accountability of special nuclear material. Increased funding is also included for cyber security activities in FY 2007. Reimbursable work is included in the numbers above; the amount for FY 2007 is $830,000.

Oak Ridge Institute for Science and Education	**1,403**	**1,359**	**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. 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. Also, there is a cyber security program, for which increased funding is requested in FY 2007. Reimbursable work is included in the numbers above; the amount for FY 2007 is $319,000.

Oak Ridge National Laboratory...	**11,891**	**9,461**	**8,396**

The Oak Ridge National Laboratory (ORNL) Safeguards and Security program includes security systems, information security, personnel security, material control and accountability, and program management. Increased funding is also included for cyber security activities in FY 2007. 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. A decrease in security systems is the result of funding provided in FY 2006 for the 2003 DBT for one time upgrades and improvements of entry points and in FY 2007 this focus has shifted to protective forces funded by Oak Ridge Office. Reimbursable work is included in the numbers above; the amount for FY 2007 is $1,945,000.

Oak Ridge Office...	**12,418**	**15,872**	**17,635**

The Oak Ridge Office Safeguards and Security program provides for contractor protective forces for ORNL. This includes protection of a Category I special nuclear material facility, Building 3019 ($12,304,000), the Spallation Neutron Source facility ($550,000), and the Federal Office Building complex ($3,808,000). Other small activities include security systems, information security, and personnel security ($623,000). Also, cyber security is funded at $350,000. The majority of the increase in FY 2007 is for protective forces to meet the FY 2003 DBT requirements at Building 3019; a corresponding decrease is taken in security systems for Oak Ridge Office and Oak Ridge National Laboratory.

Office of Scientific and Technical Information	**444**	**235**	**340**

The Office of Scientific and Technical Information's (OSTI) 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.

	FY 2005	FY 2006	FY 2007
	(dollars in thousands)		
Pacific Northwest National Laboratory	**11,133**	**10,044**	**10,993**

The Pacific Northwest National Laboratory (PNNL) Safeguards and Security program consists of program management, physical security systems, information security, personnel security, and material control and accountability. Increased funding is also included for cyber security activities in FY 2007. 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; the amount for FY 2007 is $1,222,000.

Princeton Plasma Physics Laboratory	**1,938**	**1,819**	**1,953**

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 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 cyber security program is requesting additional funds in FY 2007. Reimbursable work is included in the numbers above; the amount for FY 2007 is $54,000.

Stanford Linear Accelerator Center	**2,335**	**2,377**	**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 for which both areas are requesting increases. Reimbursable work is included in the numbers above; the amount for FY 2007 is $15,000.

Thomas Jefferson National Accelerator Facility	**1,468**	**1,231**	**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 program management and security systems. Increased funding is also included for cyber security activities in FY 2007.

All Other	**484**	**3,310**	**3,837**

Funding supports the development and management of a consistent cyber security approach across the Office of Science laboratory complex, including coordination of the CSAT visits. This funding also provides for Safeguards and Security program management needs for SC and for the Presidential E-Gov initiative of SAFECOM.

Subtotal, Safeguards and Security	**72,773**	**73,630**	**76,592**
Less Security Charge for Reimbursable Work	**-5,605**	**-5,605**	**-5,605**
Total, Safeguards and Security	**67,168**	**68,025**	**70,987**

Detailed Funding Schedule

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Ames Laboratory			
Protective Forces	157	152	152
Security Systems	34	40	40
Cyber Security	227	237	300
Personnel Security	35	33	33
Material Control and Accountability	8	5	5
Program Management	44	40	40
Total, Ames Laboratory	505	507	570
Argonne National Laboratory			
Protective Forces	2,700	3,000	3,000
Security Systems	1,098	944	744
Information Security	294	350	350
Cyber Security	1,956	1,598	1,840
Personnel Security	1,067	1,070	1,070
Material Control and Accountability	940	980	830
Program Management	616	628	628
Total, Argonne National Laboratory	8,671	8,570	8,462
Brookhaven National Laboratory			
Protective Forces	5,793	5,999	5,999
Security Systems	994	1,368	939
Information Security	545	527	527
Cyber Security	2,664	2,109	2,170
Personnel Security	290	234	234
Material Control and Accountability	392	392	498
Program Management	657	600	600
Total, Brookhaven National Laboratory	11,335	11,229	10,967
Fermi National Accelerator Laboratory			
Protective Forces	1,656	1,681	1,781
Security Systems	425	382	382
Cyber Security	758	672	900
Material Control and Accountability	45	38	38
Program Management	131	120	120
Total, Fermi National Accelerator Laboratory	3,015	2,893	3,221

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Lawrence Berkeley National Laboratory			
Protective Forces	1,645	1,578	1,578
Security Systems	1,244	790	790
Cyber Security	2,207	1,857	2,020
Personnel Security	76	9	9
Material Control and Accountability	22	14	14
Program Management	539	475	570
Total, Lawrence Berkeley National Laboratory	5,733	4,723	4,981
Oak Ridge Institute for Science and Education			
Protective Forces	297	314	314
Security Systems	71	102	102
Information Security	108	142	142
Cyber Security	534	390	520
Personnel Security	112	100	100
Program Management	281	311	311
Total, Oak Ridge Institute for Science and Education	1,403	1,359	1,489
Oak Ridge National Laboratory			
Security Systems	5,055	3,761	2,466
Information Security	411	346	346
Cyber Security	2,466	2,160	2,290
Personnel Security	1,095	1,145	1,145
Material Control and Accountability	458	458	458
Program Management	2,406	1,591	1,691
Total, Oak Ridge National Laboratory	11,891	9,461	8,396
Oak Ridge Office			
Protective Forces	11,964	12,804	16,644
Security Systems	68	2,584	157
Information Security	99	105	105
Cyber Security	—	—	350
Personnel Security	287	379	379
Total, Oak Ridge Office	12,418	15,872	17,635
Office of Scientific and Technical Information			
Protective Forces	25	15	15
Security Systems	215	30	30

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
Cyber Security	204	165	270
Program Management	—	25	25
Total, Office of Scientific and Technical Information	444	235	340
Pacific Northwest National Laboratory			
Security Systems	788	830	830
Information Security	1,946	1,861	1,861
Cyber Security	2,698	1,640	2,110
Personnel Security	1,999	2,276	2,755
Material Control and Accountability	498	498	498
Program Management	3,204	2,939	2,939
Total, Pacific Northwest National Laboratory	11,133	10,044	10,993
Princeton Plasma Physics Laboratory			
Protective Forces	910	975	975
Security Systems	63	33	33
Cyber Security	605	486	620
Program Management	360	325	325
Total, Princeton Plasma Physics Laboratory	1,938	1,819	1,953
Stanford Linear Accelerator Center			
Protective Forces	1,829	1,797	1,897
Security Systems	—	64	—
Cyber Security	506	516	540
Total, Stanford Linear Accelerator Center	2,335	2,377	2,437
Thomas Jefferson National Accelerator Facility			
Protective Forces	509	695	695
Security Systems	440	102	102
Cyber Security	447	360	440
Program Management	72	74	74
Total, Thomas Jefferson National Accelerator Facility	1,468	1,231	1,311
All Other			
Cyber Security	436	3,225	3,700
Program Management	48	85	137
Total, All Other	484	3,310	3,837
Subtotal, Safeguards and Security	72,773	73,630	76,592
Less Security Charge for Reimbursable Work	-5,605	-5,605	-5,605
Total, Safeguards and Security	67,168	68,025	70,987

Explanation of Funding Changes

	FY 2007 vs. FY 2006 ($000)
Ames Laboratory	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	+63
Argonne National Laboratory	
The decrease in security systems is the result of one-time funded items provided in FY 2006 in support of the 2003 Design Basis Threat (DBT), which is partially offset by an increase in cyber security to achieve a FISMA compliant approach to computer security.	-108
Brookhaven National Laboratory	
Decrease in FY 2007 primarily results from one-time costs provided for security systems in FY 2006.	-262
Fermi National Accelerator Laboratory	
Increase in FY 2007 primarily supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section. Also, there is an increase in protective forces for development and implementation of increased training.	+328
Lawrence Berkeley National Laboratory	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section. There is also an increase in program management for security assessments of the biological assets.	+258
Oak Ridge Institute for Science and Education	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	+130
Oak Ridge National Laboratory	
The decrease in security systems is the result of funding provided in FY 2006 for upgrades and improvements of entry points. There is a slight increase in program management for performing a vulnerability assessment for the National U233 vault in Building 3019. Also, an increase in cyber security supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	-1,065

	FY 2007 vs. FY 2006 ($000)
Oak Ridge Office	
The funding increase primarily supports additional protective force needs at the National U233 vault in Building 3019 in order to comply with the FY 2003 DBT. There is also a significant decrease in security systems due to one time costs in FY 2006 for the 2003 DBT. There is an increase in cyber security to support the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	+1,763
Office of Scientific and Technical Information	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	+105
Pacific Northwest National Laboratory	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section. Also, Personnel Security continues to increase for clearances, badging, and visitor transactions.	+949
Princeton Plasma Physics Laboratory	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	+134
Stanford Linear Accelerator Center	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section. Also, there is an increase in protective forces for development and implementation of increased training, and a slight decrease in security systems for one-time costs in FY 2006.	+60
Thomas Jefferson National Accelerator Facility	
Increase in FY 2007 supports the resources needed to achieve a FISMA compliant approach to computer security, as described in the Cyber Security section.	+80
All Other	
The increase in FY 2007 is primarily for the continuation of the CSAT visits and the closing of vulnerabilities discovered during this process.	+527
Total Funding Change, Safeguards and Security	**+2,962**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2005	FY 2006	FY 2007
General Plant Projects	1,300	320	—
Capital Equipment	1,813	651	—
Total, Capital Operating Expenses	3,113	971	—