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 [30]*49* passenger motor vehicles for replacement only, [$4,055,483,000] *including one law enforcement vehicle, one ambulance, and three buses*, *$4,721,969,000*, to remain available until expended[: *Provided*, That of the funds made available in section 130 of division H (Miscellaneous Appropriations and Offsets) of the Consolidated Appropriations Act, 2004, Public Law 108-199, as amended by section 315 of Public Law 109-103, for the Coralville, Iowa, project, $44,569,000 is rescinded]. *(Energy and Water Development and Related Agencies Appropriations Act, 2008.)*

Explanation of Change

Changes are proposed to reflect the FY 2009 funding and vehicle request.

Science
Office of Science

Overview

Appropriation Summary by Program

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Science					
Basic Energy Sciences	1,221,380	1,281,564	-11,662[a]	1,269,902	1,568,160
Advanced Scientific Computing Research	275,734	354,398	-3,225[a]	351,173	368,820
Biological and Environmental Research	480,104[b]	549,397	-5,000[a]	544,397	568,540
High Energy Physics	732,434	694,638	-5,307[ac]	689,331	804,960
Nuclear Physics	412,330	436,700	-3,974[a]	432,726	510,080
Fusion Energy Sciences	311,664	289,180	-2,632[a]	286,548	493,050
Science Laboratories Infrastructure	41,986	65,456	+1,405[ad]	66,861	110,260
Science Program Direction	166,469	179,412	-1,633[a]	177,779	203,913
Workforce Development for Teachers and Scientists	7,952	8,118	-74[a]	8,044	13,583
Safeguards and Security	75,830	76,592	-646[a]	75,946	80,603
Small Business Innovation Research/ Technology Transfer (SC funding)	86,936[e]	—	—	—	—
Subtotal, Science	3,812,819[b]	3,935,455	-32,748[a]	3,902,707	4,721,969
Congressionally-directed projects	—	125,633	-2,010[f]	123,623	—
Small Business Innovation Research/ Technology Transfer (Other DOE funding)	39,319[g]	—	—	—	—
Subtotal, Science	3,852,138[bg]	4,061,088	-34,758[acdf]	4,026,330	4,721,969
Coralville, Iowa project rescission	—	-44,569	—	-44,569	—
Less security charge for reimbursable work	-5,605	-5,605	—	-5,605	—
Use of prior year balances	-9,920	—	-3,014	-3,014	—
Total, Science	3,836,613[g]	4,010,914	-37,772[af]	3,973,142	4,721,969

[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.
[b] Includes $9,920,000 that was reprogrammed from prior year balances to support the GTL Bioenergy Research Centers.
[c] Includes $1,014,000 that was reprogrammed from prior year balances to support Fermilab operations.
[d] Includes $2,000,000 that was reprogrammed from prior year balances to support the Modernization of Laboratories Facilities project at ORNL, as directed in the Conference Report for P.L. 110–161.
[e] Reflects funding reprogrammed within the Science total to support the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs.
[f] Reflects a reduction for the 1.6% rescission in P.L. 110–161.
[g] Reflects funding transferred from other DOE appropriation accounts to support the SBIR and STTR programs.

As part of the third year of the President's American Competitiveness Initiative, the Office of Science (SC) request for Fiscal Year (FY) 2009 is $4,721,969,000; an increase of $748,827,000, or 18.8%, over the FY 2008 appropriation.

The request funds investments in basic research that are important both to the future economic competitiveness of the United States and to the success of Department of Energy (DOE) mission areas in energy security and national security; advancing the frontiers of knowledge in the physical sciences and areas of biological, environmental, and computational sciences; and providing world-class research facilities for the Nation's science enterprise.

SC provides support for the basic research and scientific and technological capabilities that underpin the Department's technically complex mission. Part of this support is in the form of large-scale scientific user facilities. SC facilities represent a sophisticated suite of instrumentation and research capabilities that meet the diverse needs of about 21,000 researchers each year and enable U.S. scientists to remain at the forefront of scientific discovery and innovation. These facilities include the world's highest energy proton accelerator (the Tevatron at Fermi National Accelerator Laboratory); the world's forefront neutron scattering facility (the Spallation Neutron Source at Oak Ridge National Laboratory), and synchrotron light sources such as the Advanced Photon Source and the Advanced Light Source for probing the structure and function of materials. The Department's five Nanoscale Science Research Centers and the computational resources at the National Energy Research Scientific Computing Center and Leadership Computing Facilities offer technological capabilities to the research community that are unmatched anywhere in the world.

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

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

SC supports basic research and technological capabilities that drive scientific discovery and innovation in the U.S. and underpin the Department's mission areas in energy, the environment, and national security. Seeking answers to fundamental scientific questions will result in a diverse array of practical applications as well as some revolutionary advances. Important contributions to meeting DOE's applied mission needs are expected through developments in materials and chemical sciences, especially at the nanoscale. Research in materials sciences will lead to the development of materials that improve efficiency, economy, environmental acceptability, and safety of energy generation, conversion, transmission, storage, and use. Research in chemistry will lead to the development of advances such as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for the production of fuels and chemicals, and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. The science, technology, and knowledge base developed from the Genomics: GTL program on understanding and harnessing the capabilities of microbial and plant systems may lead to cost-effective methods for producing new biofuels, better methods for the clean-up of legacy wastes, and tools for modifying concentrations of atmospheric carbon dioxide (CO_2) or for evaluating environmental impacts.

Computational modeling and simulation can improve our understanding of and sometimes predict the behavior of complex systems, as well as lead to the development of solutions to research problems that are insoluble by traditional and experimental approaches, or are too hazardous, time-consuming, or expensive to solve by traditional means. This includes challenges such as understanding the fundamental processes associated with fluid flow and turbulence, chemical reactivity, climate modeling and prediction, molecular structure and processes in living cells, subsurface biogeochemistry, and astrophysics.

Fusion, a fundamentally new source of energy under development, has the potential to provide a significant fraction of the world's energy by the end of the century. The international ITER project is a bold next step in fusion research, designed to produce, control, and sustain a burning plasma, where fusion processes generate sufficient energy to maintain the temperature of the plasma. Through investments in high-energy physics and nuclear physics, SC has historically provided the Nation with fundamental knowledge about the laws of nature as they apply to the basic constituents of matter and the forces between them. These investments in high energy and nuclear physics have enabled the U.S. to maintain a leading role in the development of technologies in areas such as nuclear energy, materials, semiconductors, nuclear medicine, and national security, and technologies such as the accelerator technologies leading to high-power x-ray light sources and advanced imaging techniques have been important to other fields of science.

SC‘s support for research at more than 300 colleges and universities nationwide and access to DOE's leading-edge research facilities provides valuable research and training opportunities for America's scientists, engineers, and science educators, contributing to the advancement of U.S. science and innovation and the development of the Nation‘s future workforce.

Strategic Themes and Goals and GPRA Unit Program Goals

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

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

- Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.
- Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

The programs funded by the Science appropriation have the following six GPRA Unit Program Goals:

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

- GPRA Unit Program Goal 3.1/2.51.00: Deliver Computing for Accelerated Progress in Science—Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.
- GPRA Unit Program Goal 3.1/2.48.00: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally change the nature of medical care to improve human health.
- GPRA Unit Program Goal 3.1/2.46.00: Explore the Fundamental Interactions of Energy, Matter, Time, and Space—Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe, search for possible new dimensions of space, and investigate the nature of time itself.
- GPRA Unit Program Goal 3.1/2.47.00: Explore Nuclear Matter, from Quarks to Stars—Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks, and gluons; to the stable elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability and possess radically different properties from known matter.
- GPRA Unit Program Goal 3.1/2.49.00: Bring the Power of the Stars to Earth—Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels our sun.

Contribution to Strategic Goals

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

Basic Energy Sciences (BES) contributes to Strategic Goals 3.1 and 3.2 by producing advances in the core disciplines of basic energy sciences—materials sciences, chemistry, geosciences, and physical biosciences. The scientific discoveries at the frontiers of these disciplines impact energy resources, production, conservation, efficiency, and the mitigation of adverse impacts of energy production and use—discoveries that will help accelerate progress toward long-term energy independence, economic growth, and a sustainable environment. BES also provides the Nation's researchers with world-class scientific user facilities, including a reactor and two accelerator-based neutron sources such as the Spallation Neutron Source; four operating light sources plus the Linac Coherent Light Source—an x-ray free electron laser currently under construction—and the National Synchrotron Light Source–II; five Nanoscale Science Research Centers; and three electron beam micro-characterization centers. These facilities provide important capabilities for fabricating, characterizing, and transforming materials of all kinds from metals, alloys, and ceramics to fragile bio-inspired and biological materials. In FY 2009, investments continue in basic research for the hydrogen economy, for solar energy conversion, and areas of forefront science such as ultrafast chemistry and materials, single-atom imaging and chemical imaging, emergent behavior, and complex systems, and support increases for activities related to electrical energy storage and for materials sciences and chemistry underpinning advanced nuclear energy systems.

Advanced Scientific Computing Research (ASCR) contributes to Strategic Goals 3.1 and 3.2 by advancing fundamental mathematics and computer science research that enables simulation and prediction of complex physical, chemical, and biological systems; providing the forefront computational capabilities needed by researchers to enable them to extend the frontiers of science; and delivering the fundamental networking research and facilities that link scientists across the nation to the Department-sponsored computing and experimental facilities. ASCR and its predecessors have been leaders in the computational sciences for several decades and supports research in applied mathematics, computer science, specialized algorithms, and scientific software tools that advance scientific discovery and are essential for research programs across SC and the Department. In FY 2009 the Leadership Computing Facilities (LCFs) at the Oak Ridge and Argonne national laboratories and the National Energy Research Scientific Computing Center at Lawrence Berkeley National Laboratory will continue to be supported. Beginning in FY 2009, the ASCR computing facilities will develop and implement a unified approach to supporting and maintaining software, languages, and tools that are critical to effective utilization of the machines. Support continues for research efforts in Scientific Discovery through Advanced Computing and the core research programs that enable researchers to deliver forefront science by more effectively utilizing the capabilities of the LCFs. Increases in core research in Applied Mathematics and Computer Science in FY 2009 will be targeted on long-term research needs, including support for a new joint Applied Mathematics-Computer Science Institute to focus on the challenges of computing at extreme scales that blur the boundaries between these disciplines, and for new efforts in the mathematics of large datasets.

Biological and Environmental Research (BER) contributes to Strategic Goals 3.1 and 3.2 by advancing research in genomics and systems biology of microbes and plants to harness their capabilities for energy and environmental solutions; by developing models to predict climate over decades to centuries; by developing science-based methods for cleaning up environmental contaminants and for long-term stewardship of the sites; by providing regulators with a stronger scientific basis for developing future radiation protection standards; and by advancing research in radiochemistry and imaging instrumentation and development of an artificial retina. In FY 2009, BER continues the Genomics: GTL program, supporting research at the interface of the biological, physical, and computational sciences to enable biotechnology-based solutions for DOE's energy security and environmental mission goals, including support for the three Bioenergy Research Centers started in FY 2007 and the Joint Genome Institute. The environmental remediation program continues to support fundamental research at the interfaces of biology, chemistry, geology, hydrology, and physics for solutions to environmental contamination challenges, and provides support for the Environmental Molecular Sciences Laboratory. BER leads the Department‘s participation in the interagency Climate Change Science Program, focusing on understanding the principal uncertainties of the causes and effects of climate change, including abrupt climate change, understanding the global carbon cycle, developing predictive models for climate change over decades to centuries, and supporting basic research for biological sequestration of carbon. In FY 2009, support increases for research to advance the science of climate and Earth system modeling and increase the spatial resolution of climate models.

High Energy Physics (HEP) contributes to Strategic Goals 3.1 and 3.2 by advancing understanding of the basic constituents of matter, deeper symmetries in the laws of nature at high energies, and mysterious phenomena that are commonplace in the universe, such as dark energy and dark matter. HEP uses particle accelerators and very sensitive detectors to study fundamental particle interactions at the highest possible energies as well as non-accelerator studies of cosmic particles using experiments conducted deep underground, on mountains, or in space. In FY 2009, HEP places a high priority on the operations, upgrades, and infrastructure of the two major HEP user facilities, the Tevatron Collider and the Neutrinos at the Main Injector (NuMI) beam line at Fermilab. After a very successful eight-year run, operation of the SLAC B-factory are completed in FY 2008. Funding is provided in FY 2009 to support significant analysis of data collected at the B-factory and for safe ramp-down of the facility. With completion of the scientific missions of the B-factory and Tevatron Collider by the end of this decade, the longer-term HEP program continues support for the development of new cutting-edge facilities in targeted areas (such as 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 at the Large Hadron Collider

(LHC) at CERN (the European Organization for Nuclear Research). HEP increases funding for university and laboratory based research to support U.S. researchers participating in the physics discoveries enabled by the LHC, and continues to provide support for operations and maintenance of the U.S.-built systems that are part of the LHC detectors. Support for International Linear Collider (ILC) R&D continues, but the U.S. role in the global R&D effort is reduced, resulting in a more focused but still robust program that emphasizes technical areas where the U.S. has unique or world-leading capabilities, and positions the U.S. to play a significant role in the ILC, if governments decide to proceed with project. In other accelerator technology R&D areas, funding is increasing, to begin implementation of a strategic plan for technology R&D. Specific areas targeted for increased support are short-term R&D focused on development of high-intensity proton sources; mid-term R&D directed at development of superconducting radiofrequency structures, in view of their potential for a wide range of applications; and long-term R&D on advanced accelerator technologies with the potential to provide transformational changes. The latter effort includes fabrication of a new test facility for advanced particle acceleration concepts. An upgrade of the world-leading Cryogenic Dark Matter Search is planned to begin in FY 2009, jointly funded with the National Science Foundation; and R&D continues for conceptual design for a Joint Dark Energy Mission (JDEM) space-based satellite. HEP and NASA will move forward with a joint competition and concept selection for JDEM in FY 2009, with a planned start for fabrication in FY 2010. In addition, non-accelerator-based elementary particle physics research continues in FY 2009, as does R&D for the next-generation ground- and space-based experiments to further explore the nature of dark energy.

Nuclear Physics (NP) contributes to Strategic Goals 3.1 and 3.2 by supporting peer-reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, and, in particular, to investigate the fundamental forces which hold the nucleus together and determine the detailed structure and behavior of the atomic nuclei. NP builds and supports world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda of fundamental nuclear physics and train a workforce relevant to the Department's missions for nuclear-related national security, energy, and environmental quality. 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 in FY 2009, and funds are provided to complete the Electron Beam Ion Source, which will provide RHIC with more cost-effective, reliable operations. The studies of hot, dense nuclear matter include NP enhancements to existing LHC experiments. Operation of the Continuous Electron Beam Accelerator Facility (CEBAF) continues, providing beams to better understand the structure of the nucleon. Support for construction of the 12 GeV CEBAF Upgrade is initiated in FY 2009. NP supports efforts in nuclear structure/astrophysics, fundamental interactions, and neutrinos, which include operations and related research at the Argonne Tandem Linac Accelerator System (ATLAS) and the Holifield Radioactive Ion Beam Facility (HRIBF). Funds are provided in FY 2009 for R&D and conceptual design activities for a U.S facility for rare isotope beams which will enable world-leading research opportunities in nuclear structure, nuclear astrophysics, and fundamental studies. The Fundamental Neutron Physics Beamline and neutron Electric Dipole Moment experiment will provide capabilities for studies of the fundamental properties of neutrons and to search for new physics beyond the Standard Model. Support is provided for U.S. participation in the Cryogenic Underground Observatory for Rare Events (CUORE) experiment, important for establishing the neutrino mass and determining whether the neutrino is its own antiparticle. Theoretical research is important in all program areas, and NP supports the nuclear data program, which collects, evaluates, and disseminates nuclear physics data. NP increase support in FY 2009 for basic research in the characterization of radioactive waste through advanced fuel cycle activities. Starting in FY 2009, NP assumes responsibilities for research, development, and production of stable and radioactive isotopes, previously under the DOE Office of Nuclear Energy, important for science, energy, national security applications.

Fusion Energy Sciences (FES) contributes to Strategic Goals 3.1 and 3.2 by advancing the theoretical and experimental understanding of plasma and fusion science and the means for confining plasmas to yield energy. Advances in plasma physics and associated technologies will bring the U.S. closer to making fusion energy a part of the Nation's energy solution. In addition to supporting fundamental research into the nature of fusion plasmas, FES supports the operation of a set of unique and diversified domestic experimental facilities and close collaborations with international partners on specialized facilities abroad in order to test and extend our theoretical understanding and computer models—ultimately leading to improved predictive capabilities for fusion plasmas. The FES research program, including experiments on major facilities and theory and computer modeling activities, will emphasize burning plasma research in support of preparation for the ITER scientific program. In FY 2009, the FES program will begin to develop identify critical scientific issues and missions for the next stage in the U.S. fusion research program during the ITER era which will keep it at the forefront of fusion and plasma sciences in the future. Funding is currently provided for continued fabrication of the National Compact Stellarator Experiment at the Princeton Plasma Physics Laboratory, however, a decision on the project's future will be made in FY 2008 as the project cost and schedule have changed significantly since the initial project baseline was established. FES increases support for efforts in the area of high energy density laboratory plasmas (HEDLP) as part of the HEDLP Joint Program with the National Nuclear Security Administration. FES will also initiate a Fusion Simulation Project in FY 2009 to take advantage of the many recent improvements in computational and computing capabilities for the development of a world-leading predictive plasma simulation code that can be applied to burning plasmas of the type that will be necessary for fusion energy producing power plants.

External factors that affect SC's level of performance include:

- changing mission needs as described by the DOE and SC mission statements and strategic plans;
- scientific opportunities as determined, in part, by new discoveries, proposal pressure, and scientific workshops;
- 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);
- unanticipated failures in critical components of scientific facilities that cannot be mitigated in a timely manner; and
- strategic and programmatic decisions made by non-SC funded domestic research activities and by major international research centers

Validation and Verification

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

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.50.00, Advance the Basic Science for Energy Independence (BES)	1,221,380	1,269,902	1,568,160
GPRA Unit Program Goal 3.1/2.51.00, Deliver Computing for Accelerated Progress in Science (ASCR)	275,734	351,173	368,820
GPRA Unit Program Goal 3.1/2.48.00, Harness the Power of Our Living World (BER)	480,104	544,397	568,540
GPRA Unit Program Goal 3.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time, and Space (HEP)	732,434	689,331	804,960
GPRA Unit Program Goal 3.1/2.47.00, Explore Nuclear Matter, from Quarks to Stars (NP)	412,330	432,726	510,080
GPRA Unit Program Goal 3.1/2.49.00, Bring the Power of the Stars to Earth (FES)	311,664	286,548	493,050
Subtotal, Strategic Goals 3.1 and 3.2 (Science)	3,433,646	3,574,077	4,313,610
All Other			
Science Laboratories Infrastructure	41,986	66,861	110,260
Program Direction	166,469	177,779	203,913
Workforce Development for Teachers and Scientists	7,952	8,044	13,583
Safeguards and Security	75,830	75,946	80,603
Small Business Innovation Research/Technology Transfer	126,255	—	—
Congressionally-directed projects	—	123,623	—
Total, All Other	418,492	452,253	408,359
Total, Strategic Goals 3.1 and 3.2 (Science)	3,852,138	4,026,330	4,721,969

Program Assessment Rating Tool (PART)

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

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

The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report. Roadmaps with detailed information on tracking progress toward the long-term measures have been developed with the Scientific Advisory Committees and links to these reports are provided on SC's PART website. The Scientific Advisory Committees are reviewing progress toward those measures vis-à-vis the roadmaps every three to five years. The first reviews were conducted during FY 2006 and early FY 2007. Links to the results of these reviews are provided on SC's PART website as they become available.

OMB did not complete a PART for any SC Programs for the FY 2009 Budget, but has provided SC with recommendations to further improve performance. The improvement plan action items for the current fiscal year may be found at http://ExpectMore.gov (search by program name).

SC has incorporated this feedback from OMB into the FY 2009 Budget Request decision process, and will continue to take the necessary steps to improve performance.

High-Risk, High-Return Research[a]

SC supports high-risk, high-return research as an essential part of its strategy to successfully accomplish the DOE's mission in areas of energy, environment, national security, and scientific discovery. Whether aimed at grand challenge, discovery-driven, or use-inspired science, SC programs incorporate high-risk, high-return research elements and ideas that challenge current thinking to make the fundamental breakthroughs necessary to accomplish mission and program goals. Every SC program considers a significant fraction of its supported activities to be high-risk, high-return. Because this research is integrated within research portfolios and projects, and there are many interconnected and collaborative efforts within and between the programs, it is not possible to quantitatively separate out the funding contributions to particular experiments or theoretical studies that are high-risk, high-return.

SC programs use several mechanisms to help identify and develop the "high-return" research topics and enabling technologies that form the basis of their portfolios, including Federal advisory committees, program and topical workshops, interagency working groups, National Academy of Sciences (NAS) studies, and special SC Program solicitations. Likewise, SC is evaluated periodically through Committee of Visitors reviews and NAS studies that consider, as part of those reviews, how well programs are supporting high-risk, high-return research as part of their overall portfolio.

Researchers funded through the Office of Science are working on some of the most pressing scientific and technical challenges of our age:

- Harnessing the power of microbial communities and plants for energy production from renewable sources, carbon sequestration, and environmental remediation;
- Expanding the frontiers of nanotechnology to develop materials with unprecedented properties for widespread potential scientific, energy, and industrial applications;
- Pursuing the breakthroughs in materials science, nanotechnology, biotechnology, and other fields needed to make solar energy more cost-effective;
- Demonstrating the scientific and technological feasibility of creating and controlling a sustained burning plasma to generate energy, as the next step toward making fusion power a commercial reality;

[a] In compliance with reporting requirements in America COMPETES (P.L. 110–69, section 1008).

- Using advanced computation, simulation, and modeling to understand and predict the behavior of complex systems beyond the reach of some of the most powerful experimental probes, with potentially transformational impacts on a broad range of scientific and technological undertakings;
- Understanding the origin of the universe and nature of dark matter and dark energy; and
- Resolving key uncertainties and expanding the scientific foundation needed to understand, predict, and assess the potential effects of atmospheric carbon dioxide on climate and the environment.

Pushing the frontiers of science depends on the continued availability of the most advanced scientific facilities for U.S. researchers. SC builds and operates national scientific facilities and instruments that make up the world's most sophisticated suite of research capabilities. To stay at the forefront of research capabilities SC invests in the research and development towards new instruments and facilities that continue to push the envelope of what is technically possible. For example, advanced accelerator and detector R&D for next generation accelerator-based scientific research facilities, such as synchrotron and neutron sources and high-energy particle colliders, is a priority high-risk, high-return research area supported across several SC programs. Basic research investments are also leading to state-of-the-art high-throughput instrumentation for genomics and systems biology as well as for probes for imaging ultrafast science at the nanoscale.

DOE understands the sense of Congress that, even within its annual basic research budget, funding high-risk, high-reward basic research projects requires attention. SC will establish a working group during FY 2008 to evaluate how SC's merit review criteria and program management practices promote the support of high-risk, high-return research and identify the need for and potential mechanisms for improving such support. The working group will also look at strategies to better communicate to the scientific community the high-risk, high-return research areas that are essential to accomplishing SC's mission-driven goals for the Department.

SC Funding for Selected Administration Priorities

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
American Competitiveness Initiative	3,836,613	3,973,142	4,721,969
Advanced Energy Initiative	495,021	508,376	788,111
Hydrogen Fuel Initiative	36,388	36,388	60,400
Climate Change Science Program	125,758	128,363	145,940
Climate Change Research Initiative	22,460	23,672	23,672
Climate Change Technology Program	486,525	498,965	833,301
Networking and Information Technology Research and Development	301,478	380,295	401,399
National Nanotechnology Initiative	195,511	199,534	300,259
ITER (TPC)	60,000	10,626	214,500

American Competitiveness Initiative

The American Competitiveness Initiative encompasses the entire SC budget, as part of a strategy to double overall basic research funding at select agencies over the FY 2006 level by FY 2016. The FY 2009 request is consistent with the planned profile for this initiative. The American Competitiveness Initiative is described further at http://www.whitehouse.gov/stateoftheunion/2006/aci/aci06-booklet.pdf.

Advanced Energy Initiative

SC research activities serve as an enabling function to provide a strong scientific underpinning for options identified in DOE's energy technology portfolio. SC investments today in fundamental basic research in the physical, chemical, biological, and environmental sciences can lead to the transformational breakthroughs essential for the future technologies that could change the way energy is produced, transformed, and used to meet global energy demands while limiting greenhouse gas emissions and environmental impacts. Advances in areas such as materials science, catalysis and chemical transformations, genomics and biochemistry, condensed matter physics, computational sciences, and geosciences can have game-changing impacts on the development of new transportation fuels and vehicle technologies; nuclear, hydrogen-based, and low-emission fossil-based energy technologies; electrical energy storage and transmission; efficient building technologies; and strategies for carbon capture and storage.. The FY 2009 SC request under the Advanced Energy Initiative is for $788,111,000, and supports basic research in the areas of solar energy, biomass, hydrogen, and fusion.

Hydrogen Fuel Initiative

In FY 2009, $60,400,000 is requested for basic research activities to realize the potential of a hydrogen economy. The research program is based on the BES workshop report "Basic Research Needs for the Hydrogen Economy" that can be found at http://www.science.doe.gov/production/bes/hydrogen.pdf. The 2003 report highlights the gap between our present capabilities for hydrogen production, storage, and use and those required for a competitive hydrogen economy. Detailed findings and research directions identified during the workshop are presented in the report.

Climate Change Research

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 CCRI is a set of cross-agency activities initiated in FY 2003 in areas of high priority climate change research.

- **Climate Change Science Program**: In FY 2009, 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). SC investments supported under the Climate Change Science Program in global and regional climate modeling, combined with measurement and observational experiments, can improve understanding of global carbon cycling and impacts, inform carbon management strategies, and help plan for future energy resource needs. The BER request for CCSP for FY 2009 is $145,940,000.
- **Climate Change Research Initiative**: In FY 2009, BER will continue to contribute to the CCRI from four programs: Terrestrial Carbon Processes, Climate Change Prediction, ARM, and Integrated Assessment. Activities will be focused on helping to resolve the magnitude and location of the North American carbon sink; deployment and operation of a mobile ARM facility to provide data on the effects of clouds and aerosols on the atmospheric radiation budget in regions and locations of opportunity where data is lacking or sparse; using advanced climate models to simulate potential effects of natural and human-induced climate forcing on global and regional climate and the potential effects on climate of alternative options for mitigating increases in human forcing of climate, including abrupt climate change; and developing and evaluating assessment tools needed to

study costs and benefits of potential strategies for reducing net carbon dioxide emissions. BER's FY 2009 CCRI request is $23,672,000

- **Climate Change Technology Program**: In support of the U.S. Climate Change Technology Program, the Department of Energy analyzed its energy technology portfolio across program areas to determine what actions could be taken to reduce greenhouse gas emission (GHG) intensities. The technical planning goal for this analysis was to develop a portfolio of technology options that, if deployed worldwide, could put global GHG emissions on a trajectory to achieve atmospheric concentrations of carbon between 450 to 550 parts per million (ppm). Programs were selected for the new climate change technology portfolio based on their potential to reduce carbon (in billions of tons of carbon) emissions into the atmosphere between FY 2015–2100. SC funding for the CCTP includes the FES program and activities within BES, BER, and NP. The FY 2009 SC CCTP request is $833,301,000.

Networking and Information Technology Research and Development

The activities funded by SC are coordinated with other Federal efforts through the National Information Technology Research and Development (NITRD) subcommittee of the National Science and Technology Council and its Technology Committee. The NITRD Subcommittee provides active coordination for the multiagency NITRD Program. The Subcommittee is made up of representatives from each of the participating NITRD agencies and from OMB, OSTP, and the National Coordination Office for IT R&D. The FY 2009 SC request for NITRD is $401,399,000.

National Nanotechnology Initiative

In FY 2009, there are significant shifts in the nanoscale science and engineering research activities contributing to the SC investments in research at the nanoscale and a substantial overall increase in funding. All five Nanoscale Science Research Centers are in full operation. 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, electrical energy storage, fundamental studies of materials at the nanoscale, and instrumentation for characterizing materials at the nanoscale. The FY 2009 SC request for the National Nanotechnology Initiative is $300,259,000.

ITER

ITER, an experiment to study and demonstrate the scientific and technical feasibility of fusion power, is a multi-billion dollar international research project that will, if successful, move towards developing fusion's potential as a commercially viable, clean, long-term source of energy near the middle of the century. Funding for the U.S. Contributions to ITER project increases in FY 2009 and provides for the U.S. "in-kind" hardware contributions, U.S. personnel to work at the ITER site, and funds for the U.S. share of common expenses such as infrastructure, hardware assembly, installation, and contingency. The FY 2009 SC request for ITER is $214,500,000.

Basic and Applied R&D Coordination

SC continues to coordinate basic research efforts in many areas with the Department's applied technology offices and with the National Nuclear Security Administration through collaborative processes established over the last several years. Coordination areas include energy production from conventional and alternate sources, energy conversion, energy storage and transmission, efficient energy use, waste mitigation, and national security. Specific areas include biofuels derived from biomass; solar and other renewable energy; hydrogen production, storage, and use; materials under extreme environments for the needs of energy technologies and for national security; solid-state lighting and other research promoting efficient building technologies; the Advanced Fuel Cycle, Generation IV Nuclear Energy Systems; vehicle technologies; and improving efficiencies in industrial processes. The Department's July 2006 report *DOE Strategic Research Portfolio Analysis and Coordination Plan* identified 21 additional areas of opportunity for coordination that have great potential to increase mission success. SC supports basic research and coordination efforts that underpin nearly all 21 areas, and six areas are highlighted in the FY 2009 SC budget request for enhanced R&D coordination: Advanced Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment; Electrical Energy Storage; Carbon Dioxide Capture and Storage; Characterization of Radioactive Waste; Predicting High Level Waste System Performance over Extreme Time Horizons; and High Energy Density Laboratory Plasmas. SC has sponsored scientific workshops corresponding to these focus areas in collaboration with related DOE program offices, which identified high priority basic research areas necessary for improved understanding and revolutionary breakthroughs. Other areas are being developed for increased emphasis in coming years, including materials under extreme environments, which crosscuts many areas in the Department's applied technology offices and in the National Nuclear Security Administration.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Applied mathematics for optimization of complex systems, control theory, and risk assessment			
Advanced Scientific Computing Research	—	1,900	2,000
Electrical Energy Storage			
Basic Energy Sciences	—	—	33,938
Carbon Dioxide Capture and Storage			
Basic Energy Sciences	5,915	5,915	10,915
Advanced Scientific Computing Research	—	976	976
Biological and Environmental Research	16,841	16,874	17,374
Total, Carbon Dioxide Capture and Storage	22,756	23,765	29,265
Characterization of Radioactive Waste			
Basic Energy Sciences	—	—	8,492
Biological and Environmental Research	—	—	1,500
Nuclear Physics	200	200	6,603
Total, Characterization of Radioactive Waste	200	200	16,595
Predicting High Level Waste System Performance over Extreme Time Horizons			
Basic Energy Sciences	—	—	8,492

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
High Energy Density Laboratory Plasmas			
Fusion Energy Sciences	15,459	15,942	24,636
Total, Basic and Applied R&D Coordination	38,415	41,807	114,926

Advanced Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment: ASCR supports basic research in advanced mathematics for optimization of complex systems, control theory, and risk assessment. A recommendation from the workshop focused on this subject indicated additional research emphasis in advanced mathematics could benefit the optimization of fossil fuel power generation; the nuclear fuel lifecycle; and power grid control. Such research could increase the likelihood for success in DOE strategic initiatives including FutureGen and the modernization of the power grid.

Electrical Energy Storage: About 15% of the BES funding requesting to support basic research in electrical energy storage (EES) is targeted for a formally coordinated program with DOE applied technology offices. The workshop report on this focus area noted that revolutionary breakthroughs in EES have been singled out as perhaps the most crucial need for this nation's secure energy future. The report concluded that the breakthroughs required for tomorrow's energy storage needs will be realized with fundamental research to understand the underlying processes involved in EES. The knowledge gained will in turn enable the development of novel EES concepts that incorporate revolutionary new materials and chemical processes. Such research will accelerate advances in developing novel battery concepts for hybrid and electric cars and will also help facilitate successful utilization and integration of renewable, intermittent power sources such as solar, wind, and wave energy into the utility sector, making these energy sources base load competitive.

Carbon Dioxide Capture and Storage: BES and BER support basic research in carbon dioxide capture and storage. The storage portion of this R&D coordination focus area was a subject of a BES workshop on Basic Research Needs for Geosciences in February 2007, which focused on the research challenges posed by carbon dioxide storage in deep porous geological formations. The workshop report noted that the chemical and geological processes involved in the storage of carbon dioxide are highly complex and its prediction would need an interdisciplinary approach that strongly couples experiments with theory, modeling, and computation bridging multiple length and time scales. The BES effort supports fundamental research to understand the underlying chemical, geochemical, and geophysical processes involved in subsurface sequestration sites. The BER research effort focuses on understanding, modeling, and predicting the processes that control the fate of carbon dioxide injected into geologic formations, subsurface carbon storage, and the role of microbes and plants in carbon sequestration in both marine and terrestrial environments. These aspects of this focus area were also the subject of additional SC workshops that identified basic research areas in CO_2 capture and storage that could benefit the optimization of fossil fuel power generation and the development of carbon neutral fuels.

Characterization of Radioactive Waste: BES, BER, and NP support basic research in radioactive waste characterization. This R&D coordination focus area was the subject of six SC workshops, including three BES workshops. The workshop reports noted that the materials and chemical processes involved in radioactive waste storage are highly complex and their characterization would need an interdisciplinary approach that strongly couples experiments with theory, modeling, and computation bridging multiple length and time scales. The BES effort will focus on fundamental research to understand the underlying physical and chemical processes that occur under the conditions of radioactive waste storage, which include extremes of temperature, pressure, radiation flux, and multiple complex phases. The BER research effort addresses processes that control the mobility of radiological waste in the environment. The NP research effort is focused on characterization of radioactive waste through the advanced fuel cycle activities. The NP program areas are structured as scientific disciplines with goals to understand fundamental nuclear physics. A small portion of on-going research is relevant to the issues involved with radioactive waste and related advanced fuel cycles. The knowledge gained from this fundamental research will lead to breakthroughs in radioactive waste characterization necessary for permanent solutions to nuclear waste disposal, making nuclear power a major component in primary energy usage and lessening our dependence on oil.

Predicting High Level Waste System Performance over Extreme Time Horizons: BES supports basic research in predicting high level waste (HLW) system performance over extreme time horizons. This R&D coordination focus area was a subject of a BES workshop on Basic Research Needs for Geosciences in February 2007, which focuses on research challenges posed by geological repositories for HLW. The workshop report identified major research priorities in the areas of computational thermodynamics of complex fluids and solids, nanoparticulate and colloid physics and chemistry, biogeochemistry in extreme and perturbed environments, highly reactive subsurface materials and environments, and simulation of complex multi-scale systems for ultra-long times. The knowledge gained would in turn enable finding the permanent solutions to nuclear waste disposal, making nuclear power a major component in primary energy usage and lessening our dependence on oil. It would also further advance the goal of addressing environmental remediation needs.

High Energy Density Laboratory Plasmas: In May 2007, SC and NNSA jointly sponsored a workshop to update the HEDLP scientific research agenda. Three scientific themes emerged from the workshop: enabling the grand challenge of fusion energy by high energy density laboratory plasmas; creating, probing and controlling new states of high energy densities; and, catching reactions in the act by ultra-fast dynamics. In FY 2009, the FES request expands existing HEDLP research in response to the research opportunities identified in the workshop.

Scientific Workforce

Workforce development is an important element of the SC 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 important for the development of the next generation of scientists, engineers, and science educators.

	FY 2007	FY 2008	FY 2009
Estimated Number of University Grants			
BES	1,150	1,120	1,500
ASCR	150	170	180
BER	700	715	750
HEP	200	200	200
NP	188	188	188
FES	231	233	233
Total Estimated Number of University Grants	2,619	2,626	3,051

	FY 2007	FY 2008	FY 2009
Estimated Number of Ph.D.s Supported			
BES	4,840	4,770	5,840
ASCR	615	720	745
BER	1,511	1,654	1,720
HEP	1,750	1,660	1,765
NP	981	967	1,040
FES	815	817	807
Total Estimated Number of Ph.D.s Supported	10,512	10,588	11,917
Estimated Number of Graduate Students Supported			
BES	1,580	1,550	2,000
ASCR	335	415	435
BER	400	435	460
HEP	585	585	605
NP	472	460	490
FES	350	354	344
Total Estimated Number of Graduate Students Supported	3,722	3,799	4,334

Indirect Costs and Other Items of Interest

Institutional General Plant Projects (IGPP)

Institutional General Plant Projects 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:

- 5000 Area 13.8kV distribution system upgrade—This project provides new 13.8 kV pad-mounted disconnect switches, underground duct bank and 13.8 kV cabling will be installed to integrate with the existing 13.8 kV system and to improve capacity and system reliability. TEC: $3,250,000.
- 4000 Substation Capacity Expansion—The existing 4000 substation will be reconfigured to increase its reliability and capacity. TEC: $2,300,000.
- West Campus 1500 Series Facility Renovations—The Biological and Environmental Sciences Directorate will consolidate its research activities into West Campus facilities and vacate 40,000 square feet of offices and laboratories, the majority located in 4500S. This project renovates building systems and laboratory space in the West Campus to accommodate the consolidation. TEC: $4,000,000.

The following displays IGPP funding by site:

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Argonne National Laboratory	—	1,500	6,000
Brookhaven National Laboratory	—	400	6,820
Lawrence Berkeley National Laboratory	336	500	4,100
Oak Ridge National Laboratory	6,932	14,200	14,000
Pacific Northwest National Laboratory	13	2,000	1,500
Stanford Linear Accelerator	—	—	3,000
Total, IGPP	7,281	18,600	35,420

The IGPP funding increases significantly in FY 2009 reflecting the elimination of direct funded GPP for multi-program sites, as that funding is transferred to the SLI program to support increased line item construction under the SC Infrastructure Initiative.

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 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 2007	FY 2008	FY 2009
Ames Laboratory	1,011	997	1,031
Argonne National Laboratory	29,589	29,613	31,064
Brookhaven National Laboratory	23,767	27,511	28,289
Fermi National Accelerator Laboratory	8,514	8,557	9,668
Lawrence Berkeley National Laboratory	14,006	13,138	16,099
Lawrence Livermore National Laboratory	2,850	2,887	2,953
Los Alamos National Laboratory	100	100	100
Oak Ridge Institute for Science and Education	505	317	325
Oak Ridge National Laboratory	35,711	32,655	33,341
Oak Ridge National Laboratory facilities at Y-12	620	818	818
Office of Scientific and Technical Information	301	307	314

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Pacific Northwest National Laboratory	1,971	1,917	1,340
Princeton Plasma Physics Laboratory	5,226	5,499	5,636
Sandia National Laboratories	1,999	2,045	2,096
Stanford Linear Accelerator Center	5,533	4,353	5,631
Thomas Jefferson National Accelerator Facility	3,231	2,674	2,727
Total, Indirect-Funded Maintenance and Repair	134,934	133,388	141,432

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 therefore 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 2007	FY 2008	FY 2009
Brookhaven National Laboratory	3,284	1,711	1,771
Fermilab National Accelerator Facility	3,260	3,411	3,854
Notre Dame Radiation Laboratory	151	161	169
Oak Ridge National Laboratory	16,859	14,897	15,210
Oak Ridge Office	503	550	600
Stanford Linear Accelerator Center	6,097	6,737	6,283
Thomas Jefferson National Accelerator Facility	80	52	53
Total, Direct-Funded Maintenance and Repair	30,234	27,519	27,940

Deferred Maintenance Backlog Reduction

SC is working to reduce the backlog of deferred maintenance at its laboratories as part of the Federal Real Property Initiative within the President's Management Agenda. The total deferred maintenance backlog at the end of FY 2007 is estimated to be $518,000,000[a]. This backlog includes the Argonne, Brookhaven, Lawrence Berkley, Oak Ridge, and Pacific Northwest national laboratories; the Ames Laboratory, Fermilab National Accelerator Facility, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility; and other SC facilities in Oak Ridge and Notre Dame. The Department's goals for asset condition are based on the mission dependency of the asset. For example, the asset condition index long-term (FY 2015) target for mission

[a] The FY 2008 budget reported an estimated deferred maintenance backlog of $225,000,000 at the end of the FY 2006. This reflected deferred maintenance in excess of the DOE Asset Condition Index targets. The $518,000,000 estimate reflects the total deferred maintenance backlog.

critical facilities is 0.98 or above, where the index is computed as 1 less the ratio of deferred maintenance to replacement plant value. A higher index indicates lower deferred maintenance.

SC's $518,000,000 deferred maintenance back log at the end of FY 2007 exceeded the DOE Asset Condition Index goal by $232,000,000. To reduce the deferred maintenance backlog such that SC achieves the goals, SC sets targets for each of its laboratories for reduction of the deferred maintenance backlog based on the variance from departmental goals (e.g., the 0.98 goal for mission critical facilities). The FY 2007 target for deferred maintenance reduction funding was not met due to delayed appropriations, which postponed the start of planned projects.

Deferred maintenance activities are primarily funded by the laboratories as overhead, charged to all users of the laboratory facilities. The deferred maintenance estimates in the table below are in addition to funding of day-to-day maintenance and repair amounts shown in the tables above. In order to ensure 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 table below shows the targets planned for funding of deferred maintenance backlog reduction.

A key additional strategy in reducing deferred maintenance is SC's proposed Infrastructure Modernization Initiative, which will modernize the general purpose infrastructure at SC laboratories. The initiative focuses on increased funding for line item construction projects which will result in significant additional reductions to the deferred maintenance backlog, but are not included within the indirect funding in the following table. SLI is developing measures for tracking the progress of the initiative in reducing deferred maintenance, as well as improving mission readiness, improving operational reliability and safety, and reducing the footprint and average age of facilities.

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Argonne National Laboratory	2,721	1,983	4,581
Brookhaven National Laboratory	3,799	5,374	8,147
Fermi National Accelerator Laboratory	1,621	1,900	2,800
Lawrence Berkeley National Laboratory	2,200	4,038	2,500
Oak Ridge National Laboratory	5,320	6,000	6,500
Princeton Physics Plasma Laboratory	173	177	258
Stanford Linear Accelerator Center	792	686	1,001
Thomas Jefferson National Accelerator Facility	114	646	500
Total, Deferred Maintenance Backlog Reduction	16,740	20,804[a]	26,287[a]

[a] Funding estimates may need to be updated as a result of annual reviews of asset condition and the extent of the deferred maintenance backlog. The SC infrastructure initiative and the conversion from GPP to IGPP may also further impact the FY 2009 estimate. The impact of the FY 2008 appropriation may result in adjustments to the FY 2008 deferred maintenance funding goal.

Science
Office of Science
Funding by Site by Program

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Ames Laboratory			
Basic Energy Sciences	20,268	18,906	20,882
Advanced Scientific Computing Research	1,303	1,326	1,125
Workforce Development for Teachers and Scientists	237	100	446
Safeguards and Security	946	944	974
Total, Ames Laboratory	22,754	21,276	23,427
Ames Site Office			
Science Program Direction	519	555	576
Argonne National Laboratory			
Basic Energy Sciences	184,088	173,295	181,649
Advanced Scientific Computing Research	31,904	36,411	42,591
Biological and Environmental Research	26,903	26,034	26,309
High Energy Physics	12,953	10,448	11,368
Nuclear Physics	24,851	25,339	27,253
Fusion Energy Sciences	1,019	543	40
Science Laboratories Infrastructure	3,500	389	—
Workforce Development for Teachers and Scientists	1,353	395	2,006
Safeguards and Security	8,375	8,527	8,562
Total, Argonne National Laboratory	294,946	281,381	299,778
Argonne Site Office			
Science Program Direction	3,689	4,125	4,289
Berkeley Site Office			
Science Program Direction	4,194	4,394	4,680

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Brookhaven National Laboratory			
Basic Energy Sciences	113,270	133,343	193,883
Advanced Scientific Computing Research	1,009	1,009	730
Biological and Environmental Research	21,233	17,753	16,427
High Energy Physics	40,578	40,029	45,305
Nuclear Physics	170,537	167,838	180,794
Science Laboratories Infrastructure	3,855	8,200	14,882
Workforce Development for Teachers and Scientists	636	410	533
Safeguards and Security	10,710	10,834	11,451
Total, Brookhaven National Laboratory	361,828	379,416	464,005
Brookhaven Site Office			
Science Program Direction	3,747	4,234	4,529
Chicago Office			
Basic Energy Sciences	178,733	149,786	134,601
Advanced Scientific Computing Research	39,368	34,030	47,516
Biological and Environmental Research	140,925	128,319	107,807
High Energy Physics	128,669	123,556	146,149
Nuclear Physics	66,361	67,231	63,854
Fusion Energy Sciences	133,651	143,265	139,741
Science Laboratories Infrastructure	1,282	—	1,385
Science Program Direction	28,187	26,060	31,363
Safeguards and Security	488	1,607	2,150
SBIR/STTR	126,255	—	—
Total, Chicago Office	843,919	673,854	674,566
Fermi National Accelerator Laboratory			
Advanced Scientific Computing Research	120	120	120
High Energy Physics	344,256	319,241	376,799
Nuclear Physics	288	270	—
Workforce Development for Teachers and Scientists	162	80	436
Safeguards and Security	2,908	1,686	1,742
Total, Fermi National Accelerator Laboratory	347,734	321,397	379,097

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Fermi Site Office			
Science Program Direction	2,262	2,496	2,570
Golden Field Office			
Basic Energy Sciences	—	—	4
Workforce Development for Teachers and Scientists	774	250	869
Total, Golden Field Office	774	250	873
Idaho National Laboratory			
Basic Energy Sciences	395	375	375
Biological and Environmental Research	1,364	1,575	647
Fusion Energy Sciences	2,323	2,321	2,321
Workforce Development for Teachers and Scientists	100	86	255
Total, Idaho National Laboratory	4,182	4,357	3,598
Lawrence Berkeley National Laboratory			
Basic Energy Sciences	124,169	123,451	132,528
Advanced Scientific Computing Research	75,663	86,233	94,836
Biological and Environmental Research	90,177	99,091	87,084
High Energy Physics	52,745	49,240	56,007
Nuclear Physics	22,352	22,997	24,965
Fusion Energy Sciences	4,660	4,846	4,846
Science Laboratories Infrastructure	8,961	17,417	29,956
Workforce Development for Teachers and Scientists	713	409	1,087
Safeguards and Security	4,894	4,985	5,006
Total, Lawrence Berkeley National Laboratory	384,334	408,669	436,315

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Lawrence Livermore National Laboratory			
Basic Energy Sciences	4,375	3,912	4,061
Advanced Scientific Computing Research	12,256	9,640	13,093
Biological and Environmental Research	23,805	22,318	22,492
High Energy Physics	1,570	347	300
Nuclear Physics	1,423	1,369	1,010
Fusion Energy Sciences	12,580	12,639	12,393
Workforce Development for Teachers and Scientists	111	50	289
Total, Lawrence Livermore National Laboratory	56,120	50,275	53,638
Los Alamos National Laboratory			
Basic Energy Sciences	29,372	21,576	22,936
Advanced Scientific Computing Research	4,442	4,342	4,424
Biological and Environmental Research	16,298	15,768	14,840
High Energy Physics	1,172	248	350
Nuclear Physics	10,431	11,479	14,935
Fusion Energy Sciences	3,145	2,932	2,786
Workforce Development for Teachers and Scientists	50	50	364
Total, Los Alamos National Laboratory	64,910	56,395	60,635
National Energy Technology Laboratory			
Basic Energy Sciences	—	300	—
Science Laboratories Infrastructure	115	—	—
Workforce Development for Teachers and Scientists	475	570	633
Total, National Energy Technology Laboratory	590	870	633
National Renewable Energy Laboratory			
Basic Energy Sciences	8,261	6,700	7,630
Advanced Scientific Computing Research	674	696	631
Biological and Environmental Research	1,620	1,338	1,227
Workforce Development for Teachers and Scientists	30	—	—
Total, National Renewable Energy Laboratory	10,585	8,734	9,488

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
New Brunswick Laboratory			
Science Program Direction	—	6,644	6,782
Oak Ridge Institute for Science and Education			
Basic Energy Sciences	4,100	91	660
Advanced Scientific Computing Research	2,138	2,054	2,000
Biological and Environmental Research	5,721	3,895	4,101
High Energy Physics	171	156	150
Nuclear Physics	1,133	988	695
Fusion Energy Sciences	1,158	1,287	1,400
Science Laboratories Infrastructure	117	—	—
Science Program Direction	26	—	—
Workforce Development for Teachers and Scientists	1,600	1,592	2,952
Safeguards and Security	1,585	1,579	1,617
Total, Oak Ridge Institute for Science and Education	17,749	11,642	13,575
Oak Ridge National Laboratory			
Basic Energy Sciences	303,179	304,413	316,338
Advanced Scientific Computing Research	92,353	87,119	94,721
Biological and Environmental Research	50,234	62,720	63,643
High Energy Physics	170	30	85
Nuclear Physics	23,656	24,162	33,480
Fusion Energy Sciences	80,427	28,962	231,596
Science Laboratories Infrastructure	3,069	9,535	14,103
Safeguards and Security	7,473	7,897	8,895
Total, Oak Ridge National Laboratory	560,561	524,838	762,861
Oak Ridge Office			
Biological and Environmental Research	85	50	50
Science Laboratories Infrastructure	5,079	5,033	5,079
Science Program Direction	43,584	43,450	45,341
Safeguards and Security	18,476	17,849	18,819
Total, Oak Ridge Office	67,198	66,382	69,289

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Office of Scientific and Technical Information			
Basic Energy Sciences	80	100	80
Advanced Scientific Computing Research	80	80	80
Biological and Environmental Research	353	367	373
High Energy Physics	80	100	100
Nuclear Physics	80	100	—
Fusion Energy Sciences	80	100	100
Science Program Direction	8,600	8,684	8,916
Workforce Development for Teachers and Scientists	135	120	120
Safeguards and Security	483	470	490
Total, Office of Scientific and Technical Information	9,971	10,121	10,259
Pacific Northwest National Laboratory			
Basic Energy Sciences	18,103	16,716	17,744
Advanced Scientific Computing Research	5,155	3,928	4,362
Biological and Environmental Research	91,491	90,923	92,586
Nuclear Physics	90	—	—
Fusion Energy Sciences	873	900	900
Science Laboratories Infrastructure	10,000	24,773	41,155
Workforce Development for Teachers and Scientists	760	545	1,071
Safeguards and Security	11,318	11,143	11,163
Total, Pacific Northwest National Laboratory	137,790	148,928	168,981
Pacific Northwest Site Office			
Science Program Direction	4,836	5,053	5,618
Princeton Plasma Physics Laboratory			
Advanced Scientific Computing Research	1,227	1,154	954
High Energy Physics	236	—	252
Fusion Energy Sciences	69,084	72,027	73,603
Workforce Development for Teachers and Scientists	155	155	565
Safeguards and Security	2,128	2,128	2,149
Total, Princeton Plasma Physics Laboratory	72,830	75,464	77,523

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Princeton Site Office			
Science Program Direction	1,653	1,759	1,813
Sandia National Laboratories			
Basic Energy Sciences	36,064	40,369	44,213
Advanced Scientific Computing Research	6,524	5,966	6,598
Biological and Environmental Research	2,564	2,000	1,700
Nuclear Physics	294	275	—
Fusion Energy Sciences	2,111	2,270	2,220
Workforce Development for Teachers and Scientists	152	—	676
Total, Sandia National Laboratories	47,709	50,880	55,407
Savannah River National Laboratory			
Basic Energy Sciences	300	200	300
Biological and Environmental Research	951	520	483
Fusion Energy Sciences	40	—	—
Workforce Development for Teachers and Scientists	—	—	314
Total, Savannah River National Laboratory	1,291	720	1,097
Stanford Linear Accelerator Center			
Basic Energy Sciences	194,703	181,887	215,053
Advanced Scientific Computing Research	138	338	338
Biological and Environmental Research	4,741	4,843	3,986
High Energy Physics	145,786	95,491	91,532
Science Laboratories Infrastructure	5,770	—	—
Workforce Development for Teachers and Scientists	150	150	519
Safeguards and Security	2,566	2,566	2,586
Total, Stanford Linear Accelerator Center	353,854	285,275	314,014
Stanford Site Office			
Science Program Direction	2,123	2,551	2,625

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Thomas Jefferson National Accelerator Facility			
Advanced Scientific Computing Research	29	100	100
Biological and Environmental Research	550	600	600
High Energy Physics	1,879	1,148	2,411
Nuclear Physics	89,920	94,332	117,132
Science Laboratories Infrastructure	—	—	3,700
Workforce Development for Teachers and Scientists	359	100	448
Safeguards and Security	1,376	1,376	1,411
Total, Thomas Jefferson National Accelerator Facility	94,113	97,656	125,802
Thomas Jefferson Site Office			
Science Program Direction	1,550	1,872	1,965
Washington Headquarters			
Basic Energy Sciences	1,920	94,482	275,223
Advanced Scientific Computing Research	1,351	76,627	54,601
Biological and Environmental Research	1,089	66,283	124,185
High Energy Physics	2,169	49,297	74,152
Nuclear Physics	914	16,346	45,962
Fusion Energy Sciences	513	14,456	21,104
Science Laboratories Infrastructure	238	1,514	—
Science Program Direction	61,499	65,902	82,846
Workforce Development for Teachers and Scientists	—	2,982	—
Safeguards and Security	2,104	2,355	3,588
Congressionally Directed Projects	—	123,623	—
Total, Washington Headquarters	71,823	513,867	681,661
Total, Science	3,852,138	4,026,330	4,721,969

Major Changes or Shifts by Site

Argonne National Laboratory

Basic Energy Sciences

- The Intense Pulsed Neutron Source, a short-pulsed spallation neutron source that operated as a user facility since 1981, is shut down during FY 2008, and funds are provided in FY 2009 to place the facility in a safe storage condition.

Advanced Scientific Computing Research

- The Leadership Computing Facility will be fully operational at 250-500 teraflops and will provide open high-performance computing capability with low electrical power consumption to enable scientific advances.

Science Laboratories Infrastructure

- The Building Electrical Services Upgrade, Phase II, project will be cancelled.

Brookhaven National Laboratory

Basic Energy Sciences

- The Center for Functional Nanomaterials, one of five DOE Nanoscale Science Research Centers, will be fully operational in FY 2009.
- The National Synchrotron Light Source-II (NSLS-II) will begin construction in FY 2009. NSLS-II will provide the world's finest capabilities for x ray imaging.

Nuclear Physics

- Radioisotope related activities at the Brookhaven Linear Isotope Producer (BLIP) Building 931 and Hot Cell Building 801 are transferred from the Office of Nuclear Energy to SC in FY 2009.

Science Laboratories Infrastructure

- The Interdisciplinary Science Building, Phase I, project at BNL is initiated to replace 100,000 to 120,000 square feet of old, wood and masonry buildings with a new, 87,000 to 93,000 square foot building, with state-of-the-art laboratories, associated offices and support space.

Lawrence Berkeley National Laboratory

Biological and Environmental Research

- The Joint BioEnergy Institute at Lawrence Berkeley National Laboratory will be fully operational in FY 2009.

Science Laboratories Infrastructure

- The Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, project is initiated to remedy high seismic life-safety risks by replacing three seismically "very poor" and "poor" (University of California classification) buildings and five failing trailers with one new approximately 43,000 square feet general-purpose laboratory/office building.

Los Alamos National Laboratory

Nuclear Physics

- Radioisotope related activities at the Isotope Production Facility (IPF) are transferred from the Office of Nuclear Energy to SC in FY 2009.

Oak Ridge National Laboratory

Advanced Scientific Computing Research

- The Leadership Computing Facility will be fully operational at one petaflop and will provide open high-performance computing capability to enable scientific advances.

Biological and Environmental Research

- The BioEnergy Science Center at the Oak Ridge National Laboratory will be fully operational in FY 2009.

Fusion Energy Sciences

- Funding for the U.S. Contributions to ITER MIE Project is increased in FY 2009 by $203,874,000.

Nuclear Physics

- Radioisotope related activities at hot cells in Buildings 4501 and 7920, and chemical and materials laboratories in Buildings 9204-3 and 5500 are transferred from the Office of Nuclear Energy to SC in FY 2009.

Oak Ridge Office

Science Program Direction

- Funding responsibility of the Department's nation-wide Payments Processing Center (PPC) at the Oak Ridge Financial Service Center (ORFSC) will be transferred from SC to the Department's Working Capital Fund. Each Departmental organization will be assessed an equitable share of the PPC contractor support requirements. As the responsible program for Oak Ridge, SC will continue to fund the salaries, benefits, and related expenses of the federal staff providing oversight to the ORFSC and PPC.

Princeton Plasma Physics Laboratory

Fusion Energy Sciences

- The National Compact Stellarator Experiment (NCSX) MIE project cost and schedule baseline is changing and is under discussion within the DOE. A decision as to the future of the project is expected to be made in the second quarter of FY 2008.

Stanford Linear Accelerator Center

Basic Energy Sciences

- FY 2009 marks the first full year of Basic Energy Sciences funding for SLAC linac operations as B-factory operations completed in FY 2008 and the Linac Coherent Light Source (LCLS) operations start in FY 2009. Support continues for construction and Other Project Costs of the LCLS.

High Energy Physics

- The B-factory an electron-positron collider optimized for the study of heavy quarks and operated as a user facility is shutdown after a successful run of over eight years. This marks the first time since its inception that SLAC has not had a HEP user facility operating or under construction. SLAC will begin decommissioning and decontamination of B-factory accelerator and detector components in FY 2009.

Thomas Jefferson National Accelerator Facility

Nuclear Physics

- Beginning in FY 2009, funding is provided to start construction activities for the 12 GeV Continuous Electron Beam Accelerator Facility (CEBAF) Upgrade project. When completed, the project will provide electron beams and an additional target hall (Hall D) opening a new energy regime and enhancing capabilities to study the quark structure of the nucleon and nuclei.

Science Laboratories Infrastructure

- The Technology and Engineering Development Facility project is initiated to address infrastructure inadequacies by renovating the 42-year-old Test Lab Building, constructing a new, approximately, 100,000 square foot building, and removing 22,000 square feet of obsolete building and trailer space.

Site Description

Ames Laboratory

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 39 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, which is dedicated to the preparation, purification, and characterization of rare-earth, alkaline-earth, and refractory metal and oxide materials.

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

Safeguards and Security: This program coordinates planning, policy, implementation, and oversight in the areas of security systems, protective forces, personnel security, program management, material control and accountability, and cyber security. A protective force is maintained to provide protection of personnel, equipment, and property from acts of theft, vandalism, and sabotage through facility walk-through, monitoring of electronic alarm systems, and emergency communications.

Ames Site Office

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

Argonne National Laboratory

The Argonne National Laboratory (ANL) in Argonne, Illinois, is a multiprogram laboratory located on 1,500 acres in suburban Chicago. The laboratory consists of 99 buildings (4.4 million gross square feet of space) with an average building age of 36 years.

Basic Energy Sciences: ANL is home to research activities in broad areas of materials and chemical sciences. It is also the site of three user facilities—the Advanced Photon Source (APS), 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 **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. 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. Research at EMC includes microscopy based studies on high-temperature superconducting materials, irradiation effects in metals and semiconductors, phase transformations, and processing related structure and chemistry of interfaces in thin films.
- The **Center for Nanoscale Materials** provides capabilities for developing new methods for self assembly of nanostructures, exploring the nanoscale physics and chemistry of nontraditional electronic materials, and creating new probes for exploring nanoscale phenomena. The CNM is organized around six scientific themes: nanomagnetism, bio-inorganic hybrids, nanocarbon, complex oxides, nanophotonics, and theory and simulation.

Advanced Scientific Computing Research: ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. ANL also participates in scientific application partnerships and contributes to a number of the SciDAC science application teams. Further, it participates in both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers. ANL was selected by DOE, in partnership with ORNL and PNNL, to develop a Leadership Computing Facility (LCF) for science to revitalize the U.S. effort in high end computing. As part of the LCF activity, the ANL facility will operate 250-500 teraflops of open high-performance computing with low electrical power consumption to advance science and will continue to focus on testing and evaluating leading edge computers under development.

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

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

High Energy Physics: HEP supports physics research in theoretical and experimental physics and accelerator technology R&D at ANL, using unique capabilities of the laboratory in the areas of engineering, detector technology, and advanced accelerator and computing techniques. The program had a significant presence at the recently concluded collider program at the Deutsches Elektronen-Synchrotron (DESY) laboratory in Hamburg, Germany and continues to participate in the Tevatron and neutrino research programs at Fermi National Accelerator Laboratory ("Fermilab"); analysis of data from these experimental programs will continue for several years. Other major ANL activities include work on the ATLAS (A Large Toroidal LHC Apparatus) experiment at the Large Hadron Collider, advanced accelerator R&D using the Argonne Wakefield Accelerator, and an important role in collaboration with Fermilab in the development of superconducting radio frequency technology for future accelerators, and develop of new detector technologies.

- The **Argonne Wakefield Accelerator** is an R&D testbed that focuses on the physics and technology of high-gradient, dielectric-loaded structures for accelerating electrons. Two approaches are being pursued: a collinear, e-beam driven dielectric-loaded wakefield accelerator; and a two-beam accelerator. The goal is to identify and develop techniques which may lead to more efficient, compact, and inexpensive particle accelerators for future HEP applications. Research activities at this facility include: the development of materials/coatings for high gradient research; dielectric-loaded and photonic band gap accelerating structures; left-handed meta-materials; high-power/high-brightness electron beams; and advanced beam diagnostics.

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

- The **Argonne Tandem Linac Accelerator System** National User Facility provides variable energy, precision beams of stable ions from protons through uranium, at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams; however, about 10 to 20% of the beams are rare isotope beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus, the Advanced Penning Trap. The Gammasphere detector, coupled with the Fragment Mass Analyzer, is a unique world facility for measurement of nuclei at the limits of angular momentum (high-spin states). ATLAS staff are world leaders in superconducting linear accelerator technology, with particular application in rare isotope beam facilities. The combination of versatile beams and powerful instruments enables about 400 users annually at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies. The capabilities of ATLAS are being augmented by the fabrication of the CAlifornium Rare Ion Beam Upgrade (CARIBU) as a source to provide new capabilities in neutron-rich radioactive beams.

Fusion Energy Sciences: Argonne contributes a small effort in basic plasma science.

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

Safeguards and Security: This program provides protection of nuclear materials, classified matter, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, espionage, and other hostile acts that may cause risks to national security, the health and safety of DOE and contractor employees, the public, or the environment. Program activities include security systems, material control and accountability, information and cyber security, program management, and personnel security. In addition, a protective force is maintained. These activities ensure that the facility, personnel, and assets remain safe from potential threats.

Argonne Site Office

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

Berkeley Site Office

The Berkeley Site Office provides the single federal presence with responsibility for contract performance at the Lawrence Berkeley National Laboratory. 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

The Brookhaven National Laboratory (BNL) is a multiprogram laboratory located on 5,300 acres in Upton, New York. The laboratory consists of 336 SC buildings (3.8 million gross square feet of space) with an average building age of 37 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** 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.
- The **Center for Functional Nanomaterials** focuses on understanding the chemical and physical response of nanomaterials to make functional materials such as sensors, activators, and energy-conversion devices. It also provides clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. Equipment includes 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.

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

Biological and Environmental Research: BNL operates beam lines for protein crystallography at the NSLS for use by the national biological research community, research in biological structure determination, and research into new instrumentation for detecting x-rays and neutrons. Research is also conducted in support of the Genomics: GTL program and on the molecular mechanisms of cell responses to low doses of radiation. BNL conducts molecular radiochemistry and imaging and instrumentation research, developing advanced technologies for biological imaging. The 2005 BER Distinguished Scientist for Medical Sciences is at BNL. BNL scientists support the environmental remediation sciences research program in the area of subsurface contaminant fate and transport.

- Climate change research includes the operation of the **Atmospheric Radiation Measurement (ARM)** External Data resource that provides ARM investigators with data from non-ARM sources, including satellite and ground-based systems. BNL scientists form an important part of the science team in the Atmospheric Sciences program (ASP), including providing special expertise in conducting atmospheric field campaigns and aerosol research. The ASP chief scientist is at BNL.
- BNL scientists play a leadership role in the operation of the **Free-Air Carbon Dioxide Enrichment (FACE)** experiment at the Duke Forest which seeks to understand how plants respond to elevated carbon dioxide concentrations in the atmosphere.

High Energy Physics: HEP supports physics research in theoretical and experimental physics and accelerator technology research and development (R&D) at BNL, using unique resources of the laboratory, including engineering and technology for future accelerators and detectors, advanced computational resources, and the Accelerator Test Facility. BNL serves as the host lab for the U.S. ATLAS collaboration, which participates in the research of the ATLAS detector at the Large Hadron Collider. BNL manages the program of maintenance and operations for the ATLAS detector, operates the primary U.S. analysis facility for ATLAS data, and is developing an analysis support center for U.S. based users. The group also contributes to the leadership and management of the U.S. ILC effort

BNL researchers have a leadership role in the Reactor Neutrino experiment in Daya Bay, China. BNL physicists are also involved in other neutrino physics efforts including research at the NuMI facility with the MINOS experiment at Fermilab, and R&D and planning for possible future accelerator-based neutrino experiments.

- The BNL **Accelerator Test Facility** is a user facility that supports a broad range of advanced accelerator R&D. The core capabilities include a high-brightness photoinjector electron gun, a 70 MeV linac, high power lasers synchronized to the electron beam to a picosecond level, four beam lines, and a sophisticated computer control system. Participating researchers come from universities, national laboratories, and industries. Experiments carried out in this facility are proposal-driven, and are typically in the areas involving interactions of high power electromagnetic radiation and high brightness electron beams, including laser acceleration of electrons and free-electron lasers. Other topics include the development of electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics and computer controls.

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

- The **Relativistic Heavy Ion Collider** Facility, completed in 1999, is a major unique international facility currently used by about 1,200 scientists from 19 countries. RHIC uses Tandem Van de Graaff, Booster Synchrotron, and Alternating Gradient Synchrotron (AGS) accelerators in combination to inject beams into two rings of superconducting magnets of almost 4 kilometers circumference with 6 intersection regions where the beams can collide. RHIC 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 and characterize hot, dense nuclear matter such as the predicted “quark-gluon plasma,” a form of nuclear matter thought to have existed microseconds after the “Big Bang.” It can also collide polarized protons with beams of energy up to 250 GeV per nucleon—a unique capability. Four detectors were fabricated to provide complementary measurements, with some overlap in order to cross-calibrate the measurements; the first two are still operating. 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. 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. Additional detector subsystems are being added to PHENIX to enhance its capabilities. Scientists that used the other two smaller detectors, Phobos and Broad Range Hadron Magnetic Spectrometer (BRAHMS), have completed their data acquisition programs and are focused on data analysis. International participation was 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 are being replaced by a modern, compact Electron Beam Ion Source (EBIS) and linac system which promises greater efficiency, greater reliability, and lower maintenance costs as well as the potential for future upgrades. The EBIS is a joint DOE/NASA project.

- The **National Nuclear Data Center** is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States’ repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The NNDC is a resource for a very broad user community in all aspects of nuclear technology, with relevance to homeland security and advanced fuel cycles for nuclear reactors. Nuclear Data program-funded scientists at U.S. national laboratories and universities contribute to the activities and responsibilities of the NNDC.

- The **Brookhaven Linear Isotope Producer (BLIP)** at BNL uses a linear accelerator that injects 200 million-electron-volt protons into the 33 giga-electron-volt Alternating Gradient Synchrotron. Produced isotopes, such as strontium-82, germanium-68, copper-67, and others, are used in medical diagnostic and therapeutic applications and other scientific research. The Radioisotopes Program is transferred from the Office of Nuclear Energy to the Office of Science in FY 2009.

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

Safeguards and Security: S&S activities at BNL are focused on protective forces, cyber security, personnel security, security systems, information security, program management, and material control and accountability. BNL operates a transportation division to move special nuclear materials around the site. Material control and accountability efforts focus on accurately accounting for and protecting the site's special nuclear materials.

Brookhaven Site Office

The Brookhaven Site Office provides the single federal presence with responsibility for contract performance at 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

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

Basic Energy Sciences: BES funds research at 173 academic institutions located in 48 states.

Advanced Scientific Computing Research: ASCR funds research at over 70 colleges/universities supporting over 130 principal investigators.

Biological and Environmental Research: BER funds research at over 200 institutions, including colleges/universities, private industry, and other federal and private research institutions located in 45 states, Washington, DC, and Puerto Rico.

High Energy Physics: HEP supports about 300 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: NP funds 190 research grants at 85 colleges/universities located in 34 states and the District of Columbia. Among these are grants with the Triangle Universities Nuclear Laboratory (TUNL) which includes the High Intensity Gamma Source (HIGS) at the Duke Free Electron Laser Laboratory; the Texas A&M (TAMU) Cyclotron Institute; the Yale Wright Nuclear Science Laboratory; the University of Washington Center for Experimental Nuclear and Particle Astrophysics (CENPA) and the Institute for Nuclear Theory (INT); and the Research and Engineering (R&E) Center at the Massachusetts Institute for Technology. The first three of these include accelerator facilities which offer niche capabilities and opportunities not available at the National User Facilities, or many foreign low-energy laboratories, such as specialized sources and targets, opportunities for extended experiments, and specialized instrumentation. The CENPA and R&E Center have unique infrastructure ideal for pursuing instrumentation projects important to the NP mission. The Institute for Nuclear Theory (INT) is a premier international center for new initiatives and collaborations in nuclear theory research.

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

Safeguards and Security: S&S at CH provides for contractor protective forces for the Fermi National Accelerator Laboratory and Homeland Security Presidential Directive-12 implementation cost and maintenance.

Fermi National Accelerator Laboratory

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

Advanced Scientific Computing Research: Fermilab participates in some SciDAC science application teams relevant to physics research, accelerator modeling, and distributed data. Fermilab also participates in SciDAC Centers for Enabling Technologies that focus on specific software challenges confronting users of petascale computers.

High Energy Physics: Fermilab is the principal experimental facility for HEP. Fermilab operates the **Tevatron** accelerator and colliding beam facility, which consists of a four-mile ring of superconducting magnets and two large multi-purpose detectors, and is capable of accelerating protons and antiprotons to an energy of one trillion electron volts (1 TeV). The Tevatron Collider is the highest energy proton accelerator in the world, and will remain so until the Large Hadron Collider (LHC) begins operation at

CERN in 2008. The laboratory supports two Tevatron experiments, CDF and DZero, together home to about 1,500 physicists from Fermilab and other national labs, U.S. universities, and foreign universities and research institutes.

- The Tevatron complex includes the **Neutrinos at the Main Injector (NuMI)** beamline, the world's highest intensity neutrino beam facility, which started operation in 2005. NuMI provides a controlled beam of neutrinos to the Main Injector Neutrino Oscillation (MINOS) experiment located in the Soudan Mine in Minnesota. New experiments that will make further use of the NuMI beam are planned to begin fabrication in FY 2008.
- Fermilab is host laboratory for the U.S. CMS collaboration, which conducts research using the CMS detector at the LHC. Fermilab manages the program of maintenance and operations for the CMS detector and operates the primary U.S. data analysis center for CMS. Fermilab is also the host laboratory for the LHC Accelerator Research Program which manages U.S. accelerator physicists' efforts on the commissioning, operations, and upgrades of the LHC.
- Fermilab is a leading national laboratory for research and development of future particle accelerator technologies. For example, the large scale infrastructure needed for the fabrication, processing, and testing of superconducting radio frequency (RF) cavities and cryomodules is being built at Fermilab. This includes horizontal and vertical test stands for cavity testing, high quality clean rooms and well-equipped rigging areas for assembly of cryomodules. Fermilab is the lead U.S. laboratory coordinating the national R&D program in this area.
- The laboratory is involved in R&D associated with global systems, accelerator physics, and value engineering for the ILC. Fermilab also has a significant program for R&D on advanced detector components for a variety of physics applications. The laboratory maintains and operates a fixed target beam for testing of detector elements. The facility hosts both university and international groups.

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

Fermi Site Office

The Fermi Site Office provides the single federal presence with responsibility for contract performance at 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

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 understanding coupled processes affecting contaminant transport.

Fusion Energy Sciences: Since 1978, INL has been the lead laboratory for fusion safety. As such, it has helped to develop the fusion safety database that will demonstrate the environmental and safety characteristics of both nearer term fusion devices and future fusion power plants. Research at INL focuses on the safety aspects of magnetic fusion concepts for existing and future machines, such as a burning plasma experiment, and further developing our domestic safety database using existing collaborative arrangements to conduct work on international facilities. In addition, INL has expanded their research and facilities capabilities to include tritium science activities. INL has initiated operation of the Safety and Tritium Applied Research (STAR) Facility; 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 safety codes and standards within the ITER program.

Lawrence Berkeley National Laboratory

The Lawrence Berkeley National Laboratory is a multiprogram laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The laboratory consists of 107 buildings (1.5 million gross square feet of space) with an average building age of 38 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. It is also the site of three Basic Energy Sciences 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 finish construction in FY 2012. 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 Transmission Electron Aberration Corrected Microscope will be completed in FY 2009.
- 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.

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

Biological and Environmental Research: LBNL is one of the major national laboratory partners forming the **Joint Genome Institute (JGI)**, the principal goal of which is high-throughput DNA sequencing techniques. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on microbial systems biology research as part of Genomics: GTL program. The Chief Scientist for the Low Dose Radiation Research program and the 2005 BER Distinguished Scientists for Environmental Remediation and for Life Sciences are at LBNL. LBNL operates beamlines for determination of protein structure at the ALS for use by the national and international biological research community. The ALS also supports and is used by a growing environmental science community.

LBNL supports environmental remediation sciences research and provides geophysical, biophysical, and biochemical research capabilities for field sites in that program and is participating in the NSF/DOE Environmental Molecular Sciences Institute at Pennsylvania State University.

LBNL conducts research on carbon cycling and carbon sequestration on terrestrial ecosystems to understand the processes controlling the exchange of CO_2 between terrestrial ecosystems and the atmosphere. It also conducts research on biological and ecological responses to climatic and atmospheric changes.

It also develops scalable implementation technologies that allow widely used climate models to run effectively and efficiently on massively parallel processing supercomputers.

- The **Joint BioEnergy Institute (JBEI)** at LBNL, one of three Genomics:GTL Bioenergy Research Centers, will focus attention on model plant systems (*Arabidopsis* and rice) for which the laboratory capabilities are well developed. Early results on their more tractable genomics will be shifted to potential bioenergy feedstock plants. The JBEI will experiment with *E. Coli* and yeast, two workhorse microbes for conversion, as well as *Sulfolobus solfataricus*, an organism that has undergone much less historical research. JBEI will also consider biological production of alternatives to ethanol, such as butanol.

High Energy Physics: HEP supports physics research in experimental and theoretical physics 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. LBNL participates in the research of the ATLAS detector at the Large Hadron Collider, and has a leading role in providing the software and computing infrastructure for ATLAS. LBNL physicists are also involved in neutrino physics research using reactor-produced neutrinos, and provide management expertise to the Reactor Neutrino experiment at Daya Bay, China.

LBNL also has an active program in particle astrophysics and cosmology, providing leadership in the development of innovative detectors and in the application of high energy physics analysis methods to astronomical observations. LBNL physicists lead ongoing studies of dark energy using supernovae, including providing a catalog of data on supernova as distance indicators. The SuperNova Acceleration Probe (SNAP) science team continues R&D for a space-based dark energy mission. LBNL operates the Microsystems Lab where new detector technologies have been developed for collider physics research, as well as devices to study dark energy and the cosmic microwave background. LBNL also is host to the Particle Data Group, which coordinates compilation and synthesis of high-energy physics experimental data into compendia which summarize the status of all major subfields of HEP and are updated annually.

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

Fusion Energy Sciences: LBNL has been conducting research in developing ion beams for applications to high energy density laboratory plasmas (HEDLP) 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 and the High Current Experiment. Both experiments are directed at answering the question of how ion beams can be produced with the intensity required for research in HEDLP and inertial fusion energy sciences. LBNL conducts this research together with the Lawrence Livermore National Laboratory and Princeton Plasma Physics Laboratory through the Heavy Ion Fusion Science Virtual National Laboratory.

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

Safeguards and Security: S&S at LBNL 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

Lawrence Livermore National Laboratory (LLNL) is a multiprogram laboratory located on 821 acres in Livermore, California. This laboratory was built in Livermore as a weapons laboratory 42 miles from the campus of the University of California at Berkeley to take advantage of the expertise of the university in the physical sciences.

Basic Energy Sciences: LLNL supports research in materials sciences and in geosciences research on the sources of electromagnetic responses in crustal rocks, seismology theory and modeling, the mechanisms and kinetics of low-temperature geochemical processes and the relationships among reactive fluid flow, geochemical transport, and fracture permeability.

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

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

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

High Energy Physics: HEP supports experimental physics research and technology R&D at LLNL, using unique capabilities of the laboratory primarily in the areas of engineering and detector technology and advanced accelerator R&D.

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

Fusion Energy Sciences: LLNL works with LBNL and PPPL through the Heavy-Ion Fusion Virtual National Laboratory in advancing the physics of heavy ion beams as a driver for inertial fusion energy in the long term and high energy density laboratory plasmas in the near term. It also conducts research on Fast Ignition concepts for applications in research on high energy density physics and inertial fusion energy. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak and benchmarking of fusion physics computer models with experiments such as DIII-D. LLNL 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 plasma chamber and plasma-material interactions.

Los Alamos National Laboratory

Los Alamos National Laboratory (LANL) is a multiprogram laboratory located on 30,413 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. 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 provides access to tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT supports five scientific thrusts that serve as synergistic building blocks for integration research: nano-bio-micro interfaces, nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and theory and simulation.

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

Biological and Environmental Research: LANL is one of the major national laboratory partners that comprise the JGI, the principal goal of which is high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. One of LANL's roles in the JGI involves the production of high quality "finished" DNA sequence. It also conducts research on the molecular mechanisms of cell responses to low doses of radiation and on research to understand the molecular control of genes and gene pathways in microbes. Activities in structural biology include the operation of an experimental station for protein crystallography at the LANSCE for use by the national biological research community. LANL conducts research in optical imaging as part of the artificial retina project

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

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

High Energy Physics: HEP supports theoretical physics research and technology R&D at LANL.

Nuclear Physics: NP supports a broad program of research including: a program of neutron beam research that utilized beams from the LANSCE facility to make fundamental physics measurements; the fabrication of an experiment to search for the electric dipole moment of the neutron to be located at the Fundamental Neutron Physics Beamline at the Spallation Neutron Source (SNS); a research and development effort in relativistic heavy ions using the PHENIX detector at the RHIC and development of next generation instrumentation for RHIC; research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and the "spin" structure of nucleons at RHIC using polarized proton beams; analysis of data from the Sudbury Neutrino Observatory (SNO) and Mini Booster Neutrino Experiment (MiniBooNE) experiments and reporting results on the properties of neutrinos, and research and development directed at future studies of the properties of neutrinos; 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.

- At LANL, the 100 MeV Isotope Production Facility (IPF) produces major isotopes, such as germanium-68, a calibration source for Positron Emission Tomography (PET) scanners; strontium-82, the parent of rubidium-82, used in cardiac PET imaging; and arsenic-73, used as a biomedical tracer. The Radioisotopes Program is transferred from the Office of Nuclear Energy to the Office of Science in FY 2009.

Fusion Energy Sciences: LANL has developed a substantial experimental system for research in Magnetized Target Fusion, one of the major innovative confinement concepts and a thrust area in magnetized high energy density laboratory plasmas. 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

The National Renewable Energy Laboratory (NREL) is a program-dedicated laboratory (Solar) located on 632 acres in Golden, Colorado. NREL was built to emphasize renewable energy technologies such as photovoltaics and other means of exploiting solar energy. It is the world leader in renewable energy technology development. Since its inception in 1977, NREL's sole mission has been to develop renewable energy and energy efficiency technologies and transfer these technologies to the private sector.

Basic Energy Sciences: NREL supports basic research efforts that underpin this technological emphasis at the laboratory, e.g., on overcoming semiconductor doping limits, novel and ordered semiconductor alloys, and theoretical and experimental studies of properties of advanced semiconductor alloys for prototype solar cells. It also supports research addressing the fundamental understanding of solid-state, artificial photosynthetic systems. This research includes the preparation and study of novel dye-sensitized semiconductor electrodes, characterization of the photophysical and chemical properties of quantum dots, and study of charge carrier dynamics in semiconductors.

Advanced Scientific Computing Research: NREL participates in SciDAC science application teams including efforts focused on computational nanoscience and computational biology.

New Brunswick Laboratory

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

Oak Ridge Institute for Science and Education

The Oak Ridge Institute for Science and Education (ORISE), operated by Oak Ridge Associated Universities (ORAU), is located on a 150-acre site in Oak Ridge, Tennessee. Established in 1946, ORAU is a university consortium leveraging the scientific strength of major research institutions to advance science and education by partnering with national laboratories, government agencies, and private industry. ORISE focuses on scientific initiatives to research health risks from occupational hazards, assess environmental cleanup, respond to radiation medical emergencies, support national security and emergency preparedness, and educate the next generation of scientists.

Basic Energy Sciences: ORISE supports a consortium of university and industry scientists to share the ORNL research station at NSLS to study the atomic and molecular structure of matter (known as ORSOAR, the Oak Ridge Synchrotron Organization for Advanced Research). ORISE provides administrative support for panel reviews and site reviews. It also assists with the administration of topical scientific workshops and provides administrative support for other activities such as for the reviews of construction projects. ORISE manages the **Shared Research Equipment (SHaRE)** program at ORNL. The SHaRE program makes available state-of-the-art electron beam microcharacterization facilities for collaboration with researchers from universities, industry, and other government laboratories.

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

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

High Energy Physics: ORISE provides support to the HEP program in the area of program planning and review.

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

Fusion Energy Sciences: ORISE supports the operation of the Fusion Energy Sciences Advisory Committee 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, Oak Ridge Office, participating universities, DOE laboratories, and industries.

Science Laboratories Infrastructure: SLI enables the cleanup and removal of excess facilities at ORISE.

Safeguards and Security: S&S 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

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 248 buildings (3.4 million gross square feet of space) with an average building age of 37 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); the High Flux Isotope Reactor (HFIR); and the Center for Nanophase Materials Sciences (CNMS).

- The **Spallation Neutron Source** is a next-generation short-pulse spallation neutron source for neutron scattering that is significantly more powerful (by about a factor of 10) than any other spallation neutron source 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 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. 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.
- The **Center for Nanophase Materials Sciences** integrates nanoscale science with neutron science; synthesis science; and theory, modeling, and simulation. Scientific themes include macromolecular complex systems, functional nanomaterials such as carbon nanotubes, nanoscale magnetism and transport, catalysis and nano building blocks, and nanofabrication.

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

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 Carbon Sequestration in Terrestrial Ecosystems (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 environmental remediation sciences research, including a field site for research on advancing the understanding and predictive capability of coupled hydrologic, geochemical, and microbiological processes that control the *in situ* transport, remediation, and natural attenuation of metals, radionuclides, and co-contaminants at multiple scales ranging from the molecular to the watershed.

ORNL is one of the major national laboratory partners that comprise the JGI, the principal goal of which is high-throughput DNA sequencing. One of ORNL's roles in the JGI involves the annotation (assigning biological functions to genes) of completed genomic sequences and mouse genetics. ORNL conducts research on widely used data analysis tools and information resources that can be automated to provide information on the biological function of newly discovered genes identified in high-throughput DNA sequencing projects. ORNL conducts microbial systems biology research as part of Genomics: GTL. The laboratory also operates the Laboratory for Comparative and Functional Genomics, or "Mouse House."

- The **BioEnergy Science Center (BESC)** at ORNL, one of three Genomics: GTL Bioenergy Research Centers, will focus attention on two prime candidate feedstock plants, the poplar tree and switchgrass.

High Energy Physics: HEP supports a small research effort using unique capabilities of ORNL in the area of advanced accelerator R&D.

Nuclear Physics: The major effort at ORNL is the research, development, and operations of the Holifield Radioactive Ion Beam Facility (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 (FNPB) at the Spallation Neutron Source (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 FNPB will provide cold and ultra-cold neutron beams for a user research program in fundamental interactions and symmetries.

- The **Holifield Radioactive Ion Beam Facility** is the only radioactive nuclear beam facility in the U.S. to use the isotope separator on-line (ISOL) method and is used annually by about 235 scientists for studies in nuclear structure, dynamics, and astrophysics using radioactive beams. 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. HRIBF conducts R&D on targets and ion sources and low energy ion transport for radioactive beams. The capabilities of HRIBF were augmented by the fabrication of the High Power Test Laboratory (HPTL) which provides capabilities unique in the world for the development and testing of new ion source techniques. The fabrication of a second source and transport beam-line (IRIS2) for radioactive ions will improve efficiency and reliability.

- Enriched stable isotopes are processed at materials and chemical laboratories (Building 5500 and Building 9204-3). The materials laboratory performs a wide variety of metallurgical, ceramic, and high vacuum processing techniques; the chemical laboratory performs scraping, leaching, dissolving, oxidizing processes to remove unwanted materials and place the isotope into a "chemically stable" form. Radioactive isotopes are chemically processed and packaged in hot cells in Buildings 4501 and 7920. The Radioisotopes Program is transferred from the Office of Nuclear Energy to the Office of Science in FY 2009.

Fusion Energy Sciences: ORNL develops a broad range of components that are critical for improving the research capability of fusion experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in fusion materials science, in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. The laboratory is also the site of the Controlled Fusion Atomic Data Center and its supporting research programs. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL is also a leader in stellarator theory and design and is a major partner with PPPL on the NCSX MIE project being built at PPPL. ORNL hosts the U.S. ITER Project Office and is the lead laboratory managing the U.S. Contributions to ITER MIE project.

Science Laboratories Infrastructure: SLI enables Departmental research missions at Oak Ridge by funding line item construction to maintain the general purpose infrastructure, and the cleanup and removal of excess facilities.

Safeguards and Security: S&S at Oak Ridge 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

The Oak Ridge (OR) Office directly provides corporate support (i.e., procurement, legal, finance, budget, human resources, and facilities and infrastructure) to site offices responsible for program management oversight of three major management and operating laboratories: Pacific Northwest National Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility. OR also oversees the OR Reservation and other DOE facilities in the City of Oak Ridge. Together on the Reservation and in the City of Oak Ridge there are 32 buildings (184,317 square feet) with an average age of 46 years and a total replacement plant value (RPV) of $29.0 million. The RPV of the roads and other structures on the Reservation is $47.5 million. The administrative, business, and technical expertise of OR is shared SC-wide through the Integrated Support Center concept. The OR Manager is also the single federal official with responsibility for contract performance at ORNL and the Oak Ridge Institute for Science and Education (ORISE). The Manager provides on-site presence for ORNL and ORISE with authority encompassing contract management, program and project implementation, federal stewardship, and internal operations.

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

Safeguards and Security: S&S 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

The Office of Scientific and Technical Information (OSTI) collects, preserves, and disseminates R&D information produced by DOE-sponsored research for use by DOE, the scientific community, academia, U.S. industry, and the public to expand the knowledge base of science and technology. 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-Gov systems such as the Information Bridge, Energy Citations Database, and the E-Print Network. OSTI also developed and hosts the interagency e-Gov system Science.gov, which uses breakthrough technology for simultaneously searching across more than 50 million pages in 30 federal databases involving 13 different federal agencies. Internationally, DOE (representing the United States), through OSTI's partnership with the British Library, used the same federated searching technology to open a web-based global gateway, WorldWideScience.org, to science information, covering 24 portals and databases from 17 countries. Although the majority of DOE's R&D output is open to the scientific community, a sizable share is classified or sensitive, and OSTI's responsibilities are to ensure protection and limited, appropriate access.

Pacific Northwest National Laboratory

Pacific Northwest National Laboratory is a DOE multiprogram laboratory located in Richland, Washington that supports DOE's science, national security, energy, and homeland security missions. PNNL operates the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL)—a 208,775 square feet national scientific user facility constructed by DOE that houses 375 people. PNNL also utilizes 23 Federal facilities in the 300 Area of the Hanford Reservation (543,000 square feet of space that house nearly 600 people). These facilities provide nearly 50% of the PNNL's laboratory space and 100% of its nuclear and radiological facilities. In addition, PNNL operates facilities on land owned by its parent organization, Battelle Memorial Institute (494,000 square feet), and leases an additional 775,500 square feet of office space in the Richland area occupied by approximately 2,100 staff.

Basic Energy Sciences: PNNL supports research in interfacial and surface chemistry, inorganic molecular clusters, analytical chemistry, and applications of theoretical chemistry to understanding surface. Geosciences research includes theoretical and experimental studies to improve our understanding of phase change phenomena in microchannels. Also supported is research on stress corrosion and corrosion fatigue, interfacial dynamics during heterogeneous deformation, irradiation assisted stress corrosion cracking, bulk defect and defect processing in ceramics, chemistry and physics of ceramic surfaces, and interfacial deformation mechanisms in aluminum alloys.

Advanced Scientific Computing Research: PNNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools. PNNL also participates in several SciDAC science application teams and both SciDAC Centers for Enabling Technologies and SciDAC Institutes that focus on specific software challenges confronting users of petascale computers. PNNL, in partnership with ANL and ORNL, was selected by DOE to develop Leadership Computing for science to revitalize the U.S. effort in high end computing.

Biological and Environmental Research: PNNL is home to the William R. Wiley **Environmental Molecular Sciences Laboratory (EMSL),** a national scientific user facility that is an integrated experimental and computational resource for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation. EMSL provides unique ultra high field mass spectrometry and nuclear magnetic resonance spectrometry instruments, a high performance computer, and a wide variety of other cutting edge analytical capabilities for use by the national research community.

PNNL conducts a wide variety of research in subsurface environmental remediation science, with emphases on biogeochemistry and fate and transport of radionuclides. PNNL is participating in the National Science Foundation (NSF)/DOE Environmental Molecular Sciences Institutes at Pennsylvania

State University and Stanford University. It also conducts research into new instrumentation for microscopic imaging of biological systems.

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

PNNL is one of the major national laboratory partners that comprise the JGI, the principal goal of which is high-throughput DNA sequencing. One of PNNL's roles in the JGI involves proteomics research (identifying all the proteins found in cells). PNNL conducts research on the molecular mechanisms of cell responses to low doses of radiation and on the development of high throughput approaches for characterizing all of the proteins (the proteome) being expressed by cells under specific environmental conditions. PNNL conducts microbial systems biology research as part of Genomics: GTL. The Chief Scientist for the Genomics: GTL program is at PNNL.

Fusion Energy Sciences: PNNL has focused on research on materials that can survive in a fusion neutron environment. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper, and ferrite steels as part of the U.S. fusion materials team.

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

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

Pacific Northwest Site Office

The Pacific Northwest Site Office provides the single federal presence with responsibility for contract performance at 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

Princeton Plasma Physics Laboratory (PPPL) is a program-dedicated laboratory (Fusion Energy Sciences) located on 88 acres in Plainsboro, New Jersey. The laboratory consists of 36 buildings (721,000 gross square feet of space) with an average building age of 33 years. DOE does not own the land.

Advanced Scientific Computing Research: PPPL participates in SciDAC science application teams related to fusion science.

High Energy Physics: HEP 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 DOE laboratory devoted primarily to plasma and fusion science. The laboratory hosts experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the National Spherical Torus Experiment (NSTX), which is an innovative toroidal confinement device, closely related to the tokamak, and is fabricating the National Compact Stellarator Experiment (NCSX), another innovative confinement device. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks and the NSF Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas in the U.S., as well as several large tokamak facilities abroad, including Joint European Torus in the United Kingdom, JT-60U in Japan, and Korean Superconducting Tokamak Reactor Advanced Research in 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 for research in high energy density laboratory plasmas through Heavy Ion Fusion Science Virtual National Laboratory. Through its association with Princeton University, PPPL provides high quality education in fusion-related sciences, having produced more than 200 Ph.D. graduates since its founding in 1951.

Safeguards and Security: S&S at PPPL 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 program consists of protective forces, security systems, cyber security, and program management.

Princeton Site Office

The Princeton Site Office provides the single federal presence with responsibility for contract performance at PPPL. 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

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 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 the Center for Integrated Nanotechnologies (CINT).

- 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 provides access to tools and expertise to explore the continuum from scientific discovery to the integration of nanostructures into the microworld and the macroworld. CINT supports five scientific thrusts that serve as synergistic building blocks for integration research: nano-bio-micro interfaces, nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and theory and simulation.

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

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

Fusion Energy Sciences: Sandia plays a lead role in developing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and the walls of fusion devices. Material 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. Sandia supports a wide variety of domestic and international experiments in the areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing. Sandia 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

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

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

Stanford Linear Accelerator Center

The Stanford Linear Accelerator Center (SLAC) is located on 426 acres of Stanford University land in Menlo Park, California. SLAC is a laboratory dedicated to the design, construction, and operation of state-of-the-art electron accelerators and related experimental facilities for use in high-energy physics and photon science and has operated the 2 mile long Stanford Linear Accelerator (linac) since 1966. SLAC consists of 115 buildings (1.7 million gross square feet of space) with the average age of 30 years. In addition, SLAC will become the site of the world's first x-ray laser, the Linac Coherent Light Source (LCLS) in 2009. Funding for operations of the SLAC linac is transitioning from High Energy Physics to Basic Energy Sciences, with full funding by Basic Energy Sciences starting in FY 2009.

SLAC houses the Kavli Institute for Particle Astrophysics and Cosmology (KIPAC), which is an independent laboratory of Stanford University.

Basic Energy Sciences: SLAC is the home of the **Stanford Synchrotron Radiation Laboratory** and peer-reviewed research projects associated with SSRL. The facility is used by astronomers, biologists, chemical engineers, chemists, electrical engineers, environmental scientists, geologists, materials scientists, and physicists. A research program is conducted at SSRL with emphasis in both the x-ray and ultraviolet regions of the spectrum. SSRL scientists are experts in photoemission studies of high-temperature superconductors and in x-ray scattering. The SPEAR 3 upgrade at SSRL provided major improvements that increase the brightness of the ring for all experimental stations.

Advanced Scientific Computing Research: SLAC participates in SciDAC science application teams relevant to physics research, accelerator modeling, and distributed data.

Biological and Environmental Research: SLAC operates nine SSRL beamlines for structural molecular biology. This program involves synchrotron radiation-based research and technology developments in structural molecular biology that focus on protein crystallography, x-ray small angle scattering diffraction, and x-ray absorption spectroscopy for determining the structures of complex proteins of many biological consequences. Beamlines at SSRL also support a growing environmental science user community.

High Energy Physics: SLAC operates the **B-factory,** which consists of PEP-II, a high energy asymmetric electron-positron collider, and a multi-purpose detector, BaBar. The B-factory was constructed to support a search for and high-precision study of CP symmetry violation in the B meson system, and began operations in 1999. The last year of B-factory operations for HEP will be FY 2008. The BaBar detector collaboration includes about 600 physicists from SLAC and other national laboratories, U.S. universities, and foreign universities and research institutes. A small group at SLAC also participates in the research program of the ATLAS detector at the Large Hadron Collider.

SLAC researchers are also working at the frontier of particle astrophysics. In 2006, SLAC completed construction of the detector for the Gamma Ray Large Array Telescope (GLAST) which will be launched into earth orbit in 2007. SLAC physicists and a user community will analyze the GLAST data through 2012. SLAC and Stanford University are also home to the Kavli Institute for Particle Astrophysics and Cosmology, which brings together researchers studying a broad range of fundamental questions about the universe, from theoretical astrophysics to dark matter and dark energy.

SLAC is a major contributor to the leadership and development of the proposed International Linear Collider, applying their expertise to nearly all aspects of the project. The laboratory is at the forefront of damping ring and beam delivery designs, required to ensure the beam brightness and precision control needed for the experimental program. SLAC also represents the center of expertise for design, fabrication, and testing of radio frequency power systems used to energize the accelerator components. The laboratory also participates in R&D for advanced detector technologies, with emphasis on software, simulation, and electronics.

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

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

Stanford Site Office

The Stanford Site Office provides the single federal presence with responsibility for contract performance at 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

Thomas Jefferson National Accelerator Facility is an Office of Science laboratory (Nuclear Physics) located on 206 acres (DOE-owned) in Newport News, Virginia focused on the exploration of nuclear and nucleon structure. The laboratory consists of 64 buildings (477,000 gross square feet of space) with an average building age of 15 years, 2 state-leased buildings, 23 real property trailers, and 10 other structures and facilities. The laboratory was constructed over the period FY 1987–1995.

Advanced Scientific Computing Research: TJNAF participates in SciDAC science application teams relevant to physics research, accelerator modeling, and distributed data.

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

Nuclear Physics: The centerpiece of TJNAF is the **Continuous Electron Beam Accelerator Facility (CEBAF)**, a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure. The facility has an international user community of about 1,200 researchers. Polarized electron beams up to 5.7 GeV can be provided by CEBAF simultaneously to 3 different experimental halls. Hall A is designed for spectroscopy and few-body measurements. Hall B has a large acceptance detector, CLAS, for detecting multiple charged particles coming from a scattering reaction. Hall C is designed for flexibility to incorporate a wide variety of different experiments. Its core equipment consists of two medium resolution spectrometers for detecting high momentum or unstable particles. The G0 detector in Hall C allows a detailed mapping of the strange quark contribution to nucleon structure. Also in Hall C, a new detector, Q-weak, is being developed to measure the weak charge of the proton by a collaboration of laboratory and university groups, in partnership with the NSF. TJNAF supports a group that does theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy Physics. TJNAF research and engineering staff are world experts in superconducting radio frequency (SRF) accelerator technology; their expertise is being used in the development of the 12 GeV Upgrade for CEBAF and the proposed International Linear Collider, and was utilized for the completed the Spallation Neutron Source. The 12 GeV CEBAF Upgrade initiates construction activities in FY 2009 and will provide researchers with the opportunity to study quark confinement, one of the greatest mysteries of modern physics.

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

The Technology and Engineering Development Facility project is initiated to renovate about 89,000 square feet in the Test Lab Building and remove over 10,000 square feet of inadequate and obsolete work space. The project will also construct a new building which will provide approximately 100,000 square feet of space to eliminate severe overcrowding and improve workflow and productivity by co-locating the engineering and technical functions currently spread across the Laboratory.

Safeguards and Security: TJNAF has a guard force (protective force) that provides 24-hour services for the accelerator site and after-hours property protection security for the entire site. Other security programs include cyber security, program management, material control and accountability, and security systems.

Thomas Jefferson Site Office

The Thomas Jefferson Site Office provides the single federal presence with responsibility for contract performance at 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 SC-wide issues, operational policy, scientific program development, and management functions supporting a broad spectrum of scientific disciplines and program offices. These disciplines include ASCR, BES, BER, FES, HEP, and NP, and also include activities conducted by the Workforce Development for Teachers and Scientists program. Additionally, support is included for management of workforce program direction and infrastructure through policy, technical, and administrative support staff responsible for budget and planning; general administration; information technology; infrastructure management; construction management; safeguards and security; and environment, safety, and health within the framework set by the Department. Funded expenses include salaries, benefits, travel, general administrative support services and technical expertise, as well as other costs funded through interdepartmental transfers and interagency transfers.

Basic Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Basic Energy Sciences					
Research					
Materials Sciences and Engineering	879,323	955,094	-1,034[ab]	954,060	1,125,579
Chemical Sciences, Geosciences, and Energy Biosciences	217,028	232,348	-9,771[ab]	222,577	297,113
Total, Research	1,096,351	1,187,442	-10,805[a]	1,176,637	1,422,692
Construction	125,029	94,122	-857[a]	93,265	145,468
Total, Basic Energy Sciences	1,221,380[c]	1,281,564	-11,662[a]	1,269,902	1,568,160
Stanford Linear Accelerator Center (SLAC) Linac Operations (non-add)	(37,550)	(61,500)	(—)	(61,500)	(96,700)
Basic Energy Sciences, excluding SLAC Linac Operations (non-add)[d]	(1,183,830)	(1,220,064)	(-11,662[a])	(1,208,402)	(1,471,460)

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 108-153, "21st Century Nanotechnology Research and Development Act", 2003
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007"

Mission

The mission of the BES program—a multipurpose, scientific research effort—is to foster and support fundamental research to expand the scientific foundations for new and improved energy technologies and for understanding and mitigating the environmental impacts of energy use. The portfolio supports work in the natural sciences by emphasizing fundamental research in materials sciences, chemistry, geosciences, and physical biosciences.

Basic research supported by the BES program touches virtually every aspect of energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation. Research in materials

[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008 as follows: Materials Sciences and Engineering ($-8,691,000); Chemical Sciences, Geosciences, and Energy Biosciences ($-2,114,000); and Construction ($-857,000).
[b] Includes a reallocation of funding within BES in accordance with the Energy and Water Conference Report, as follows: Materials Sciences and Engineering ($+7,657,000) and Chemical Sciences, Geosciences, and Energy Biosciences ($-7,657,000) to optimize funding for research and facility operations within the BES program.
[c] Total is reduced by $28,870,000: $25,777,000 of which was transferred to the Small Business Innovative Research (SBIR) program and $3,093,000 of which was transferred to the Small Business Technology Transfer (STTR) program.
[d] The SLAC linear accelerator (linac) supported operations of the B-Factory funded by High Energy Physics (HEP) through FY 2008. The linac also supports operations of the Linac Coherent Light Source currently under construction and funded by BES. SC has been transitioning funding of the SLAC linac from HEP to BES, with FY 2009 representing the first year of total funding by BES. BES totals without SLAC linac funding are presented to display program growth exclusive of this functional transfer.

sciences and engineering leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety of energy generation, conversion, transmission, storage, and use. For example, research on toughened ceramics results in improved high-speed cutting tools, engine turbines, and a host of other applications requiring lightweight, high-temperature materials. Research in chemistry leads to the development of advances such as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for the production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. Research in geosciences results in advanced monitoring and measurement techniques for reservoir definition and an understanding the fluid dynamics of complex fluids through porous and fractured subsurface rock. Research in the molecular and biochemical nature of photosynthesis aids the development of solar photo-energy conversion. History has taught us that seeking answers to fundamental questions results in a diverse array of practical applications as well as some remarkable revolutionary advances.

Strategic and GPRA Unit Program Goals

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

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

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

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

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

Contribution to GPRA Unit Program Goal 3.1/2.50.00, 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 this goal by producing seminal advances in the core disciplines of the basic energy sciences. These subprograms build leading research programs that provide world-class, peer-reviewed research results cognizant of both DOE mission needs and new scientific opportunities. The following indicators establish specific long-term (ten-year) goals in scientific advancement that the BES program is committed to and against which progress can be measured.

Design, model, fabricate, characterize, analyze, assemble, and use a variety of new materials and structures, including metals, alloys, ceramics, polymers, biomaterials and more—particularly at the nanoscale—for energy-related applications.

Understand, model, and control chemical reactivity and energy transfer processes in the gas phase, in solutions, at interfaces, and on surfaces for energy-related applications, employing lessons from inorganic and biological systems.

Develop new concepts and improve existing methods to assure a secure energy future, e.g., for solar energy conversion and for other energy sources.

Conceive, design, fabricate, and use new scientific instruments to characterize and ultimately control materials, especially instruments for x-ray, neutron, and electron beam scattering and for use with high magnetic and electric fields.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.50.00 Advance the Basic Science for Energy Independence			
Basic Energy Sciences	1,221,380	1,269,902	1,568,160

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 3.1/2.50.00 (Advance the Basic Science for Energy Independence)					
Materials Sciences and Engineering					
Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 100 nm and in the soft x-ray region was measured at 19 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 90 nm and in the soft x-ray region was measured at 15 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 90 nm and in the soft x-ray region was measured at 15 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 90 nm and in the soft x-ray region was measured at 15 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal].	Maintain spatial resolutions for imaging in the hard x-ray region of <100 nm and in the soft x-ray region of <18 nm, and spatial information limit for an electron microscope of 0.08 nm[a]	Maintain spatial resolutions for imaging in the hard x-ray region of <100 nm and in the soft x-ray region of <18 nm, and spatial information limit for an electron microscope of 0.08 nm.[a]
Improve temporal resolution: X-ray pulses were measured at 20 femtoseconds in duration with an intensity of 10,000 photons per pulse. [Met Goal]	Improve temporal resolution: X-ray pulses were measured at 70 femtoseconds in duration with an intensity of 100 million photons per pulse. [Met Goal]	Improve temporal resolution: X-ray pulses were measured at 70 femtoseconds in duration with an intensity of 100 million photons per pulse. [Met Goal]	Improve temporal resolution: X-ray pulses were measured at 70 femtoseconds in duration with an intensity of 100 million photons per pulse. [Met Goal]	Maintain x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse ($>10^8$ photons/pulse).[a]	Maintain x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse ($>10^8$ photons/pulse).[a]
Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 91.9%). [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 97.7%). [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 96.7%). [Met Goal]	Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 102.1%). [Met Goal]	Achieve an average operation time of the scientific user facilities as a percentage of the total scheduled annual operating time of greater than 90%.	Achieve an average operation time of the scientific user facilities as a percentage of the total scheduled annual operating time of greater than 90%.
Chemical Sciences, Geosciences, and Energy Biosciences					
As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a two-dimensional combustion reacting flow simulation was performed involving 44 reacting species and 518,400 grid points. [Met Goal]	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a three-dimensional combustion reacting flow simulation was performed involving 11 reacting species and 0.5 billion grid points. [Met Goal]	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a three-dimensional combustion reacting flow simulation was performed involving 33 reacting species and 21.2 million grid points. [Met Goal]	Improve Simulation: Beginning in FY 2007, increasing the size of the simulation will no longer provide useful new information. Thus, this measure was discontinued.		

[a] No further improvement is expected in FY 2008-FY 2013 for these measures, because the current suite of instruments has met the maximum performance level. This target is a measure of SC's intent to maintain the maximum level of performance for users of the current SC facilities until the next generation of instruments and facilities becomes available.

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
Construction					
Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: +1.3% cost variance and +0.8% schedule variance). [Met Goal]	Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: +0.2% cost variance and -2.5% schedule variance). [Met Goal]	Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: -1.7% cost variance and -3.2% schedule variance). [Met Goal]	Cost and timetables were maintained within 10% of the baselines given in the construction project datasheets for all construction projects ongoing during the year (Results: -2.7% cost variance and -10.4% schedule variance). [Goal of <10% Variance Not Met]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects. In FY08, it is at least 10% and 10%, respectively.	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects. In FY09, it is at least 10% and 10%, respectively.

Means and Strategies

The BES program supports fundamental peer-reviewed research to create new knowledge in areas important to the BES mission and supports the design, construction, and operation of a wide array of scientific user facilities for the preparation and examination of materials properties and their physical and chemical transformations. All research projects and facilities 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:

- changing mission needs as described by the DOE and SC mission statements and strategic plans;
- scientific opportunities as determined, in part, by scientific workshops and proposals received by researchers;
- 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;
- unanticipated failures in critical components of scientific user facilities or major research programs; and
- strategic and programmatic decisions made by non-DOE funded domestic research activities and by major international research centers.

The BES program in fundamental science is coordinated with the activities of other programs within the Office of Science, with programs of the DOE technology office and the National Nuclear Security Administration, and with programs of other federal agencies. BES also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, nuclear energy, reduced environmental impacts of energy production and use, national security, and future energy sources.

Validation and Verification

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

Program Assessment Rating Tool (PART)

The Department has implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government’s portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The BES program has incorporated feedback from OMB into the FY 2009 budget request and has taken or will take the necessary steps to continue to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the BES program a score of 93% overall, which corresponds to a rating of “Effective.” OMB found the program to be strategically driven and well managed. Outside expert panels have validated the program’s merit-based review processes ensuring that research supported is relevant and of very high quality. The assessment also found that BES has developed a limited number of adequate performance measures, which are continued for FY 2009. 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. Roadmaps, developed in consultation with the Basic Energy Sciences Advisory Committee (BESAC), will guide triennial reviews by BESAC of progress toward achieving the long term Performance Measures. These roadmaps are posted on the SC website. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

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

Basic and Applied R&D Coordination

Electrical Energy Storage (EES): The Basic Energy Sciences program is proposing $33,938,000 in the request to support basic research in electrical energy storage (EES). Within this funding, $2,000,000 is targeted for a formally coordinated program with DOE applied technology offices. This R&D coordination focus area was the subject of a BES workshop held in April 2007. The workshop report noted that revolutionary breakthroughs in EES have been singled out as perhaps the most crucial need for this nation's secure energy future. The report concluded that the breakthroughs required for tomorrow's energy storage needs will be realized with fundamental research to understand the underlying processes involved in EES. The knowledge gained will in turn enable the development of novel EES concepts that incorporate revolutionary new materials and chemical processes. Such research will accelerate advances in developing novel battery concepts for hybrid and electric cars, lessening our dependence on oil. It will also help facilitate successful utilization and integration of renewable, intermittent power sources such as solar, wind, and wave energy into the utility sector, making these energy sources base load competitive.

Applied technology offices within DOE that could benefit from the Electrical Energy Storage research coordination effort include: the Offices of Electricity Delivery and Energy Reliability (for research on utility-scale electrical energy storage) and Energy Efficiency and Renewable Energy (the FreedomCAR and Vehicle Technologies program for research on batteries for vehicle technologies and Solar Energy Technologies program for research on energy storage for solar energy utilization).

Carbon Dioxide Capture and Storage: The Basic Energy Sciences program is proposing $10,915,000 in the request to support basic research in carbon dioxide capture and storage. The storage portion of this R&D coordination focus area was the subject of a BES workshop on Basic Research Needs for Geosciences in February 2007, which focused on the research challenges posed by carbon dioxide storage in deep porous geological formations. The workshop report noted that the chemical and geological processes involved in the storage of carbon dioxide are highly complex and its prediction would need an interdisciplinary approach that strongly couples experiments with theory, modeling, and computation bridging multiple length and time scales. Major research priorities were identified in the areas of multiphase fluid flow and materials transport in deep formations, dynamic imaging of flow and transport, fluid-induced rock deformation, transport properties, and *in situ* characterization of fluid trapping, isolation and immobilization, mineral fluid interface complexity and dynamics, and developing high-resolution modeling capabilities for predicting storage site performance. The report concluded that the breakthroughs in carbon dioxide storage required for carbon-free utilization of fossil fuels will be realized with fundamental research to understand the underlying chemical, geochemical, and geophysical processes involved in subsurface sequestration sites. Research in carbon dioxide capture would include fundamental studies of chemical processes and membranes for the separation of carbon dioxide from both post- and pre-combustion gas streams.

Applied technology offices within DOE that could benefit from the Carbon Dioxide Capture and Storage research coordination effort include the Office of Fossil Energy.

Characterization of Radioactive Waste: The Basic Energy Sciences program is proposing $8,492,000 in the request to support basic research in radioactive waste characterization. This R&D coordination focus area was the subject of a number of BES workshops, including the Basic Research Needs for Advanced Nuclear Energy Systems (July 2006), Basic Research Needs for Geosciences (February 2007), and Basic Research Needs for Materials under Extreme Environments (June 2007). The workshop reports noted that the materials and chemical processes involved in radioactive waste storage are highly complex and their characterization would need an interdisciplinary approach that strongly couples experiments with theory, modeling, and computation bridging multiple length and time scales. The reports concluded that the breakthroughs in radioactive waste characterization required for tomorrow's energy needs will be realized with fundamental research to understand the underlying physical and chemical processes that occur under the conditions of radioactive waste storage, which include extremes of temperature, pressure, radiation flux, and multiple complex phases. The knowledge gained will in turn enable finding the permanent solutions to nuclear waste disposal, making nuclear power a major component in primary energy usage and lessening our dependence on oil.

Applied technology offices within DOE that could benefit from the Characterization of Radioactive Waste research coordination effort include the Offices of Nuclear Energy, Environmental Management, and Civilian Radioactive Waste Management.

Predicting High Level Waste System Performance over Extreme Time Horizons: The Basic Energy Sciences program is proposing $8,492,000 in the request to support basic research in predicting high level waste (HLW) system performance over extreme time horizons. This R&D coordination focus area was the subject of a BES workshop on Basic Research Needs for Geosciences in February 2007, which focuses on research challenges posed by geological repositories for HLW. The workshop report noted that the chemical and geological processes involved in the performance of HLW systems over extreme time scales are highly complex and its prediction would need an interdisciplinary approach that strongly couples experiments with theory, modeling, and computation bridging multiple length and time scales. The report concluded that the breakthroughs in predicting HLW performance required for tomorrow's energy needs will be realized with fundamental research to understand the underlying chemical, geochemical, and geophysical processes involved in the highly radioactive environments. Major research priorities were identified in the areas of computational thermodynamics of complex fluids and solids, nanoparticulate and colloid physics and chemistry, biogeochemistry in extreme and perturbed environments, highly reactive subsurface materials and environments, and simulation of complex multi-scale systems for ultra-long times. The knowledge gained will in turn enable finding the permanent solutions to nuclear waste disposal, making nuclear power a major component in primary energy usage and lessening our dependence on oil. It will further advance the goal of addressing environmental remediation needs

Applied technology offices within DOE that could benefit from the Predicting High Level Waste System Performance over Extreme Time Horizons research coordination effort include: Offices of Nuclear Energy; Environmental Management; and the Civilian Radioactive Waste Management Program.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Electrical Energy Storage			
Materials Sciences and Engineering Research	—	—	16,969
Chemical Sciences, Geosciences, and Energy Biosciences	—	—	16,969
Total, Electrical Energy Storage	—	—	33,938
Carbon Dioxide Capture and Storage			
Chemical Sciences, Geosciences, and Energy Biosciences	5,915	5,915	10,915
Characterization of Radioactive Waste			
Chemical Sciences, Geosciences, and Energy Biosciences	—	—	8,492
Predicting High Level Waste System Performance Over Extreme Time Horizons			
Materials Sciences and Engineering Research	—	—	8,492
Total, Basic and Applied R&D Coordination	5,915	5,915	61,837

Overview

BES and its predecessor organizations have supported a program of fundamental research focused on critical mission needs of the nation for over five decades. The federal program that became BES began with a research effort initiated to help defend our nation during World War II. The diversified program was organized into the Division of Research with the establishment of the Atomic Energy Commission in 1946 and was later renamed Basic Energy Sciences as it continued to evolve through legislation included in the Atomic Energy Act of 1954, the Energy Reorganization Act of 1974, the Department of Energy Organization Act of 1977, and the Energy Policy Acts of 1992 and 2005.

Today, the BES program is one of the nation's largest sponsors of research in the natural sciences. It is uniquely responsible for supporting fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences impacting energy resources, production, conversion, transmission, storage, efficiency, and waste mitigation. In FY 2007, the program funded research in more than 173 academic institutions located in 48 states and in 13 DOE laboratories located in 9 states. BES supports a large extramural research program, with approximately 40% of the program's research activities sited at academic institutions.

The BES program also supports world-class scientific user facilities, providing outstanding capabilities for imaging; for characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological samples; and for studying the chemical transformation of materials. The BES synchrotron radiation light sources, the neutron scattering facilities, and the electron beam characterization centers represent the largest and best collection of such facilities supported by a single organization in the world. Annually, more than 10,000 researchers from universities, national laboratories, and industrial laboratories will perform experiments at these facilities in the coming years. Spurred by results of past investments and by innovations in accelerator concepts, the BES program continues its pioneering role in the development of new generations of scientific research instruments and facilities.

The 2001 "National Energy Policy" noted that the U.S. economy grew by 126% since 1973, but energy use increased by only 30%. Approximately one-half to two-thirds of the savings resulted from technological improvements in products and services that allow consumers to enjoy more energy services without commensurate increases in energy demand. At the heart of these improvements is fundamental research. 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 at the nanoscale with properties that are not found in nature. 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 coordinated programs and facilities that together transcend what individuals alone can do. The program in nanoscale science, including the construction and operation of Nanoscale Science Research Centers, continues that philosophy.

Advisory and Consultative Activities

Charges are provided to BESAC by the Under Secretary for Science, who also serves as the Director of the Office of Science. During the past few years, BESAC has provided advice on new directions in nanoscale science and complex systems; on the operation of the major scientific user facilities; on the need for new, "next-generation" facilities for x-ray, neutron, and electron-beam scattering; on performance measurement; on the quality of the BES program management and its consequent impacts on the program portfolio; on new directions in research relating to specific aspects of fundamental science such as catalysis, biomolecular materials, and computational modeling at the nanoscale; on the fundamental research challenges posed by the Department's energy missions; on a 20-year roadmap for BES facilities; and on theory and computation needs across the entire portfolio of BES research.

Of particular note is the 2003 BESAC report, "Basic Research Needs to Assure a Secure Energy Future," which prompted 10 follow-on "Basic Research Needs" workshops supported by BES in the past 5 years in the areas of the hydrogen economy; solar energy utilization; superconductivity; solid-state lighting; advanced nuclear energy systems; combustion of 21st century transportation fuels; electrical-energy storage; geosciences as it relates to the storage of energy wastes (the long-term storage of both nuclear waste and CO_2); materials under extreme environments; and catalysis for energy applications. Together these workshops attracted over 1,500 participants from universities, industry, and DOE laboratories. BESAC is now charged with summarizing the results of these 10 workshops and relating this summary to the science themes identified in the 2007 BESAC Grand Challenges study.

Information and reports for all of the above mentioned advisory and consultative activities are available on the BESAC website (http://www.science.doe.gov/bes/BESAC/BESAC.htm). Other studies are commissioned as needed using the National Academy of Science's National Research Council and other independent groups.

Facility Reviews

Facilities are reviewed using external, independent review committees operating according to the procedures established for peer review of BES laboratory programs and facilities (http://www.science.doe.gov/bes/labreview.html). Important aspects of the reviews include assessments of the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; user satisfaction; facility staffing levels; R&D activities to advance the facility; management of the facility; and long-range goals of the facility.

These reviews have identified both best practices and issues, including those associated with mature facilities. For example, the light sources experienced a quadrupling of the number of users in the decade of the 1990s, and their reviews highlighted the change that occurred as they 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 outcomes of these reviews helped develop new models of operation for existing light sources and for the Spallation Neutron Source, which was completed in FY 2006, and the National Synchrotron Light Source-II (NSLS-II), which will begin construction in FY 2009.

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

Planning and Priority Setting

Because the BES program supports a broad portfolio, planning is an ongoing activity. Many long-range planning exercises for elements of the BES program are performed under the auspices of BESAC. Inputs to prioritization include overall scientific opportunity, projected investment opportunity, DOE mission need, and Administration and Departmental priorities.

These considerations have led to the following: increased investments in science at the nanoscale to take advantage of the remarkable knowledge gained from atomic-scale understanding of materials; increased investments for operations of the major user facilities in recognition of the quadrupling of users in the past decade and to reap the rewards of the capital investments in the facilities themselves; increased investments for instrumentation at the facilities so that the quality of the instruments will match the world-class quality of the facilities; increased investments for ultrafast science to probe processes that happen on the timescale of chemical reactions; and increases for targeted program areas for which both scientific opportunity and mission need are high (e.g., basic research for effective solar energy utilization). Construction of new user facilities, such as the Spallation Neutron Source, follows from input from BESAC and from broad, national strategies that include the input from multiple federal agencies.

Significant Program Shifts

- The Intense Pulsed Neutron Source is closed in FY 2008 due to competing priorities. Funds are provided in FY 2009 to maintain the facility in a safe storage condition.

Additional research funding is provided in the following areas:

- **Basic research for the hydrogen economy (+$24,012,000).** Research to realize the potential of a hydrogen economy will be increased from $36,388,000 to $60,400,000. The research program is based on the BES workshop report "Basic Research Needs for the Hydrogen Economy."
- **Basic research for effective solar energy utilization (+$33,369,000).** Investments will be focused in three areas: solar-to-electric, solar-to-fuels, and solar-to-thermal conversions. 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.

- **Basic research for advanced nuclear energy systems (+$16,984,000).** 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).
- **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.
- **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). 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 (+$19,600,000).** 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-energydensity 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 (+$5,000,000).** Investments will develop and apply new methods to measure the chemical behavior of individual molecules and reactions, with high resolution in both space and time in order to elucidate fundamental principles of chemical processes at the nanoscale level. The research will build on current single-molecule spectroscopies and microscopies by adding simultaneous time-dependent characterization of evolving chemical processes, ultimately with femtosecond time resolution.
- **Electrical energy storage (EES) ($+33,938,000)**. The use of electricity generated from intermittent, renewable sources requires efficient EES in order to effectively integrate it into the baseload grid system and to use it in transportation applications. A number of specific areas of research for both batteries and electrochemical capacitors have been identified: (1) Efficacy of structure in energy storage—new approaches combining theory and synthesis for the design and optimization of materials architectures including self-healing, self-regulation, failure-tolerance, and impurity-sequestration. (2) Charge transfer and transport—molecular scale understanding of interfacial

electron transfer. (3) Electrolytes—electrolytes with strong ionic solvation, yet weak ion-ion interactions, high fluidity, and controlled reactivity. (4) Probes of energy storage chemistry and physics at all time and length scales—analytical tools capable of monitoring changes in structure and composition at interfaces and in bulk phases with spatial resolution from atomic to mesoscopic levels and temporal resolution down to femtoseconds. (5) Multi-scale modeling—computational tools with improved integration of length and time scales to understand the complex physical and chemical processes that occur in EES from the molecular to system scales.

- **Carbon Sequestration ($+5,000,000)**. Research will be undertaken to develop the scientific understanding that will underpin novel technological approaches to deep underground carbon sequestration. Research directions identified in the 2007 BES workshop report "Basic Research Needs for Geosciences" include: (1) understanding geochemical processes relevant to the dimensions of subsurface sequestration sites and incorporating realistic chemistry of reacting flowing fluids into predictive models of geological formations; (2) development of critical geophysical measurement techniques to enable remote probing and tracking of important chemical and physical processes within rock formations at depth, including capture of rock heterogeneity; and (3) development and application of fluid-flow measurement approaches and simulation tools that can link, and explicitly couple, chemical and physical processes at multiple scales.

Materials Sciences and Engineering

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Materials Sciences and Engineering			
Materials Sciences and Engineering Research	265,092	283,851	379,393
Facilities Operations	614,231	645,869	719,247
SBIR/STTR	—	24,340	26,939
Total, Materials Sciences and Engineering	879,323	954,060	1,125,579

Description

This subprogram includes two major activities. The first activity is fundamental experimental and theoretical research to provide the knowledge base for the discovery and design of new materials with novel structures, functions, and properties.

The second activity supported by this subprogram is the R&D, planning, and operation of scientific user facilities for the fabrication of materials and for the examination of materials through x-ray, neutron, and electron beam scattering; the former is accomplished through five Nanoscale Science Research Centers and the latter is accomplished through the world's largest suite of synchrotron radiation light source facilities, neutron scattering facilities, and electron-beam microcharacterization centers.

In condensed matter and materials physics—including activities in experimental condensed matter physics, theoretical condensed matter physics, materials behavior and radiation effects, and physical behavior of materials—research is supported to understand, design, and control materials properties and function. These goals are accomplished through studies of the relationship of materials structures to their electrical, optical, magnetic, surface reactivity, and mechanical properties and the way in which materials respond to external forces such as stress, chemical and electrochemical environments, radiation, and the proximity of materials to surfaces and interfaces. The activity emphasizes correlation effects, which can lead to the formation of new particles, new phases of matter, and unexpected phenomena. The theoretical efforts focus on the development of advanced computer algorithms and codes to treat large or complex systems.

In scattering and instrumentation sciences—including activities in neutron and x-ray scattering and electron and scanning microscopies—research is supported on the fundamental interactions of photons, neutrons, and electrons with matter to understand the atomic, electronic, and magnetic structures and excitations of materials and the relationship of these structures and excitations to materials properties and behavior. Major research areas include fundamental dynamics in complex materials, correlated electron systems, nanostructures, and the characterization of novel systems. The development of next-generation neutron, x-ray, and electron microscopy instrumentation is a key element of this portfolio.

In materials discovery, design, and synthesis—including activities in synthesis and processing science, materials chemistry, and biomolecular materials—research is supported in the discovery and design of novel materials and the development of innovative materials synthesis and processing methods. Major research thrust areas include nanoscale synthesis, organization of nanostructures into macroscopic structures, solid state chemistry, polymers and polymer composites, surface and interfacial chemistry including electrochemistry and electro-catalysis, synthesis, and processing science including biomimetic and bioinspired routes to functional materials and complex structures.

In the R&D, planning, and operations of facilities, synchrotron radiation light source facilities, neutron scattering facilities, electron-beam microcharacterization centers, and nanoscale science research centers provide a unique set of analytical tools that reveal the atomic structure and functions of complex materials. Annually, the BES user facilities are visited by 10,000 scientists and engineers in many fields. These facilities are unique and improve the competitiveness of the U.S. scientific and technological establishment. Also supported are research activities leading to the improvement of today's facilities and to the development of next generation facilities.

Selected FY 2007 Research Accomplishments

- *Nanoscale building blocks for energy technologies.* Nanoscale materials hold great promise for enabling new concepts and approaches in energy applications, because the elementary steps of energy conversion take place at the nanometer length scale. There are many recent examples where quantum confinement in nanomaterials has produced unexpected phenomena exploitable in energy technologies. Taking advantage of the unique electronic structure in semiconductor quantum dots, containing only 50 atoms each, researchers have demonstrated white light emission with high luminescence efficiency, offering a revolutionary new nanomaterial for use in solid-state lighting. Equally interesting is the metallic quantum dot that exhibits exceptionally long electron-spin relaxation time due to discrete energy levels; the long relaxation time is needed for quantum information processing and for the development of quantum computers. Nanoscale phenomena have also been shown to produce a new-class of thermoelectrics, materials that convert heat into electricity. With reducing size, changes in the corresponding electronic structure afford independent control over the electron and phonon transport, enabling optimization of both electrical and thermal properties. Such control is not available in bulk materials. By embedding nanoscale structures into bulk thermoelectric materials, researchers have melded nanoscale electronic control with bulk-level microstructural tailoring, leading to very high thermoelectric conversion efficiencies. Such advances are especially critical for the conversion of waste heat in vehicles into useful electricity, which increases fuel efficiency. These results demonstrate that the control of materials and phenomena at the nanoscale can lead to revolutionary breakthroughs in energy relevant technologies.
- *New materials for radiation environments.* Materials capable of resisting damage from intense radiation are essential for advanced nuclear energy systems. The primary radiation-damage mechanism in materials involves the creation and accumulation of structural defects such as atomic dislocations, vacancies, and other anomalies. Multiple defects could lead to the collapse of the ordered crystalline structure of the material, adversely affecting the integrity of material components used in nuclear energy systems. Recent studies have shown that materials can be made radiation-damage resistant by creating structures that actually accommodate radiation-induced structural disorder on the atomic scale. Complex oxides are candidate materials for these structures, because they exhibit strong tendencies for natural atomic disordering. As a result, the formation of radiation-induced defects causes very little structural change, allowing the crystal structure to remain mechanically intact. The materials exhibit good radiation tolerance after high-level radiation exposure. Similarly, radiation damage can be accommodated in composite materials containing a high volume fraction of nanoscale interfaces. The interfaces are found to possess a strong affinity for defects, thereby catalytically removing them from the bulk of the material. The accumulation of large numbers of defects would otherwise lead to embrittlement and loss of mechanical integrity.

The research has provided fundamental insight into tailoring the atomic structure of materials to achieve substantial improvements in radiation damage tolerance.

- *Emergent electronic behavior from graphene.* Researchers have found through electrical transport measurements that electron dynamics are relativistic in graphene, essentially an unrolled single-walled carbon nanotube. Specifically, under proper conditions, the electrons in graphene behave like massless particles such as photons and move through the material at a constant speed with very little scattering. Furthermore, the electrons in graphene exhibit the quantum Hall effect (QHE) at room temperature, which surprised the condensed matter physics community since QHE was only observed at ultra low temperature previously. This may lead to the development of ultrafast energy-efficient devices fabricated from materials as simple as a single atomic layer of carbon atoms.
- *Ultrafast movies of the turbulent magnetic nanoworld.* The extremely short timescale of magnetic switching, normally in the nanosecond or shorter regime, has prevented the direct visualization of the switching process until now. With recent advances in ultrafast x-ray techniques in conjunction with the advent of state-of-the-art x-ray microscopy, researchers have succeeded for the first time in observing the spin-injection process by motion pictures with 200 picoseconds (2×10^{-10} seconds) frame speed and 30 nm spatial resolution.
- *Catalytic breakthrough boosts hydrogen fuel cells.* Catalysis is vital to the operation of hydrogen fuel cells for reducing kinetic barriers and improving electrochemical reaction efficiencies. By alloying platinum single crystals with nickel, which preferentially enriches the second layer beneath the surface, researchers have altered the electronic structure of surface states that control catalytic activity. The study has revealed that the sub-surface layers could play a significant role in controlling the catalytic activity. The knowledge gained has enabled further control of the bond strengths among the catalyst, reactant, and blocking species, leading to significant improvements in catalytic stability and performance, including a 90-fold improvement in activity over pure platinum for the oxygen-reducing cathodic fuel cell reaction. This novel basic science approach demonstrates a new route for an advanced concept in nanoscale catalyst assembly.

Selected FY 2007 Facility Accomplishments

- *The Spallation Neutron Source (SNS) completes its first full year of operation.* The SNS beam power has been steadily increased during the first operation year to a power of 185 kilowatts, a world record for pulsed spallation sources. During FY 2007, the SNS delivered 3,500 hours of neutron production time, including more than 1,800 hours for users on three instruments, a backscattering spectrometer and two reflectometers. The SNS has actively reached out to users by coordinating the "Imaging and Neutrons 2006" conference; supporting a short course, "Neutron Scattering in Earth Sciences;" and sponsoring a booth at the American Crystallographic Association annual meeting.
- *The High Flux Isotope Reactor (HFIR) resumes regular operation after major upgrades.* HFIR has resumed operation after several infrastructure and system modifications. A super-critical hydrogen cold source, which operates at 18 Kelvin and provides world-class cold neutron brightness to instruments through four super-mirror neutron guides, has been installed in one of the HFIR beamlines. Several facility modifications have been performed to provide the new systems and infrastructure necessary to safely operate the cold source at cryogenic temperatures in a reactor environment and to enable safe and reliable transmission of the cold neutron beam to the adjacent cold neutron scattering guide hall. In FY 2007, HFIR has operated for three complete cycles. With successful cold source operation, two small-angle neutron scattering instruments were added in 2007 and are currently being commissioned. Nearly 100 users conducted experiments at HFIR in

FY 2007. In addition to neutron production, 234 experiment capsules were irradiated for medical and commercial isotope development and for fusion energy development, including for ITER and US/Japan Collaborative programs.

- *Synchrotron radiation light sources again host more than 8,000 users.* The steady increase in numbers of light source users from 1,657 in FY 1990 to 8,538 in FY 2007 is expected to continue through FY 2009. In anticipation of further expansion of the number of users, BES is increasing user support funding at all of the light sources and is adding new space, with the new User Support Building at the ALS as one example. In FY 2007, SSRL studies on carbon-hydrogen bonds in carbon nanotubes showed that almost complete hydrogenation is possible, corresponding to a hydrogen storage capacity of more than seven weight percent. At the APS, it was shown that the lowest thermal conductivity ever measured for a dense solid resulted from synthesizing a tungsten diselenide sample with random crystal plane stacking; materials with low thermal conductivity could lead to more energy efficient engine design in the future.
- *Full operations at four of the five Nanoscale Science Research Centers.* The first of the five BES Nanoscale Science Research Centers (NSRCs) completed its first full year of operation as a user facility in FY 2006. Three more NSRCs completed installation of initial technical equipment and transitioned to full user operations mode in FY 2007, with the fifth NSRC completing building construction. They are major scientific user facilities in which leading-edge synthesis and processing capabilities are integrated with exceptional tools and expertise for characterization and with corresponding resources for theory, modeling, and simulation. The NSRCs have established a joint ES&H (Environmental, Safety, and Health) working group, which has documented an “Approach to Nanomaterials ES&H” that provides guidance and suggestions on practices and procedures; this document has been widely disseminated and accepted both within and beyond the DOE community.
- *Electron microscopy centers reveal new materials properties and crystal growth modes.* Scientific advances enabled by electron scattering at these facilities span a wide range of materials and phenomena. One example is *in-situ* microscopy use to reveal that epitaxial growth of palladium islands on ruthenium surfaces occurs via a “snake-like” motion that gives rise to nanoscale labyrinth patterns, rather than a more standard and expected “step-like” linear growth mechanism. These studies are a first step in understanding the connection between surface morphology and alloying, and towards controlling surface structure and composition patterns.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Materials Sciences and Engineering Research	**265,092**	**283,851**	**379,393**
▪ **Experimental Condensed Matter Physics**	**42,720**	**40,720**	**50,509**

This activity supports experimental condensed matter physics emphasizing the relationship between the electronic structure and the properties of complex materials, often at the nanoscale. The focus is on systems whose behavior derives from strong correlation effects of electrons as manifested in superconducting, semi-conducting, magnetic, thermoelectric, and optical properties. Also supported is the development of new techniques and instruments for characterizing the electronic states and properties of materials under extreme conditions, such as in ultra low temperatures (millikelvin), in ultra high magnetic fields (100 Tesla), and at ultrafast time scales (femtosecond). Capital equipment is provided for scanning tunneling microscopes, electron detectors, superconducting magnets, and physical properties measurement instruments.

Improving the understanding of the electronic behavior of materials on the nanoscale is relevant to the DOE mission, as these structures offer enhanced properties and could lead to dramatic improvements in energy generation, delivery, use, and conversion technologies. Specifically, research efforts in understanding the fundamental mechanisms in superconductivity, the elementary energy conversion steps in photovoltaics, and the energetics of hydrogen storage provide the major scientific underpinnings for the respective energy technologies. This activity also supports basic research in semiconductor and spin-based electronics of interest for the next generation information technology and electronics industries.

In FY 2009, funding will be provided ($+2,500,000) to initiate a national network for the synthesis of new materials and the growth of high quality single crystals for the exploration of new physical phenomena. This activity will enable U.S. scientists with the state-of-the-art synthetic capabilities to produce crystals of novel materials with the highest quality; and to train the next generation of scientists capable of growing high quality crystals. The single crystal growth efforts will provide high-quality single crystal samples to enable researchers to fully utilize the capabilities at the advanced neutron and x-ray light sources. Major activities will continue in the development of nanomaterials for hydrogen storage ($+3,350,000), 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, thermal management, super-strong lightweight materials, hydrogen storage, and electrical power transmission. A particular emphasis is the study of photovoltaics for solar energy use ($+3,939,000).

	FY 2007	FY 2008	FY 2009
▪ **Theoretical Condensed Matter Physics**	**23,208**	**25,832**	**36,190**

This activity was formerly named Condensed Matter Theory. The activity supports theoretical condensed matter physics with emphasis on the theory, modeling, and simulation of electronic correlations. A major thrust is nanoscale science, where links between the electronic, optical, mechanical, and magnetic properties of nanostructures and their size, shape, topology, and composition are poorly understood. Other major research areas include strongly correlated electron systems, quantum transport, superconductivity, magnetism, and optics. Development of theory targeted at aiding the experimental technique design and interpretation of experimental results is also emphasized. This activity supports the Computational Materials Science Network, which forms collaborating teams from diverse disciplines to address the increasing complexity of many current research issues. The activity also supports large-scale computation to perform complex calculations dictated by fundamental theory or to perform complex system simulations with joint funding from the Advanced Scientific Computing Research program. Capital equipment funding will be provided for items such as computer workstations and clusters.

This activity provides the fundamental knowledge leading to predicting the reliability and lifetime of energy use and conversion approaches and develops opportunities for next generation energy technology. Specific examples include inverse design of compound semiconductors for unprecedented solar photovoltaic conversion efficiency; solid-state approaches to improving capacity and kinetics of hydrogen storage; and ion transport mechanisms for fuel cell applications.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

In FY 2009, there is an increase to support theory, modeling and simulation to understand mechanisms governing the complex physical and chemical processes for high density electrical energy storage ($+2,000,000). Emphasis will be on developing multi-scale computational tools and methods with integration of length and time scales to aid design of interfaces in batteries and ultracapacitors. Predictive models of the kinetics of materials phase changes, especially those accompanying charge transfer, transport, and evolution in electrode microstructures, will be critical to provide detailed insight into electrochemical processes at the molecular level. An enhancement will be made to theoretical efforts concerning emergent behavior research ($+1,500,000). The research aims at understanding the nature and origin of highly correlated states in strongly interacting systems that have spin, charge, lattice, and orbital degrees of freedom and that are often intrinsically inhomogeneous on nanometer length scales or smaller. The proposed program will encompass both theoretical and computational approaches capable of interrogating systems to gain direct insight on the mechanisms underpinning the cooperative behavior. Within this funding, there is an increase to support new theory, modeling, and simulation of materials for high-capacity solid-state hydrogen storage ($+2,938,000) and materials for solar energy use ($+1,920,000). A major emphasis of the program is obtaining a theoretical understanding of nanoscale phenomena in materials for energy use, storage, and transmission ($+2,000,000).

▪ **Mechanical Behavior and Radiation Effects**	**12,626**	**13,620**	**23,112**

This activity supports basic research to understand defects in materials and their effects on the load-bearing properties of strength, structure, deformation, and failure. Defect formation, growth, migration, and propagation are examined by coordinated experimental and modeling efforts over a wide range of spatial and temporal scales. Topics include deformation of ultra-fine scale materials, radiation-resistant material fundamentals, and intelligent microstructural design for increased strength, formability, and fracture resistance. The goals are to develop predictive models for the design of materials having superior mechanical properties and radiation resistance. Capital equipment funding is provided for high temperature furnaces, nanoscale mechanical property measurement tools, and ion-beam processing instrumentation.

The abilities to predict materials performance and reliability and to address service life extension issues are important to the DOE mission areas of fossil, fusion, and nuclear energy conversion; radioactive waste storage; environmental cleanup; and defense. Among the key materials performance goals for these technologies are good load-bearing capacity, failure and fatigue resistance, fracture toughness and impact resistance, high-temperature strength and dimensional stability, ductility and deformability, and radiation tolerance. Since materials from large-scale nuclear reactor components to nanoscale electronic switches undergo mechanical stress and are subjected to ionizing radiation, this activity provides the fundamental scientific underpinning to enable the advancement of high-efficiency and safe energy generation, use, and storage as well as transportation systems.

In FY 2009, there is an increase to enhance core research in high-temperature mechanical behavior and radiation effects in materials under extreme conditions ($+1,000,000). Of particular interest are environments involving energetic flux, chemical reactive stimulants, thermomechanical processes, and magnetic and electric fields. The primary emphasis will be on discovering novel phenomena and materials for improved performance with superior functionality. Additional funds are also requested

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

for new basic research to develop a new generation of robust materials for utilization in high-temperature and irradiation-probe environments for advanced nuclear energy systems ($+8,492,000). The emphasis of this research will be devoted to establishing unified models to predict the mechanical and degradation behavior of solids over multiple length and time scales through new and emerging advanced scientific facilities and high-performance parallel-computing platforms. Novel in-situ experiments in realistic environments will be closely integrated with theoretical/computational efforts to develop a fundamental understanding of degradation mechanisms and kinetics over multiple scales from atomistic to micron and nanosecond to decades. Such advances in this area will provide the underpinning science that will enable licensing nuclear waste packages for emplacement in the Yucca Mountain repository and the discovery of new materials for use within Generation-IV nuclear reactors and other nuclear energy systems, such as accelerator-driven nuclear fission and transmutation.

	FY 2007	FY 2008	FY 2009
▪ **Physical Behavior of Materials**	**25,964**	**25,960**	**33,539**

This activity supports basic research on the behavior of materials in response to external stimuli, such as temperature, electromagnetic fields, chemical environments, and the proximity effects of surfaces and interfaces. Emphasis is on the relationships between performance (such as electrical, magnetic, optical, electrochemical, and thermal performance) and the microstructure and defects in the material. Included within the activity are research in aqueous, galvanic, and high-temperature gaseous corrosion and their mitigation; the relationship of crystal defects to semiconducting, superconducting, and magnetic properties; phase equilibria and kinetics of reactions in materials in hostile environments; and diffusion and transport phenomena. Basic research is also supported to develop new instrumentation, including *in-situ* experimental tools, and to probe the physical behavior in real environments encountered in energy applications. Capital equipment funding is provided for items such as physical property measurement tools that include spectroscopic and analytical instruments for chemical and electrochemical analysis.

The research supported by this activity underpins the DOE mission by developing the basic science necessary for improving materials reliability in chemical, electrical, and electrochemical applications and for improving the generation and storage of energy. With increased demands being placed on materials in energy-relevant environments, such as extreme temperatures, strong magnetic fields, and hostile chemical conditions, understanding how materials behavior is linked to the surroundings and treatment history is critical. DOE mission-relevant topics include corrosion; photovoltaics for solar energy conversion; fast-ion conducting electrolytes for batteries and fuel cells; novel magnetic materials for low magnetic loss power generation; magnetocaloric materials for high-efficiency refrigeration; new materials for high-temperature gasification.

In FY 2009, there is an increase to initiate new research to develop new concepts underpinning electrolyte development ($+1,500,000). The emphasis of this research will be on establishing a fundamental understanding of the interactions that occur in electrolyte systems—ion-ion, ion-solvent, and ion-electrode. Such knowledge will permit the formulation of novel designed electrolytes with significant improvements in electrical energy storage devices. Funding will include support for new solar conversion research ($+3,379,000). To achieve low solar cost-to-power ratios, basic research into new materials and processes are needed, which include new photoconversion materials, such as polycrystalline, nanocrystalline, and organic materials to replace expensive single

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

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. The program will continue to emphasize the vigorous exploration of nanoscale phenomena ($+2,000,000), which will afford new opportunities to dramatically improve energy relevant materials. Research related to the hydrogen economy will also be supported ($+700,000).

▪ **Neutron and X-ray Scattering**	**38,943**	**38,940**	**52,098**

This activity supports basic research on the fundamental interactions of photons and neutrons with matter to achieve an understanding of the atomic, electronic, and magnetic structures and excitations of materials and the relationships of these structures and excitations to materials properties. The main emphasis is on x-ray and neutron scattering, spectroscopy, and imaging research, primarily at major BES-supported user facilities. The development and improvement of next-generation instrumentation, novel detectors, sample environments, data analysis, tools, and technology for producing polarized neutrons, are key aspects of this activity. Instrumentation development and experimental research in ultrafast materials science, including research aimed at generating, manipulating, and detecting ultrashort and ultrahigh-peak-power electron, x-ray, and laser pulses to study ultrafast physical phenomena in materials, is an integral part of the portfolio. Capital equipment funding is provided for items such as detectors, monochromators, focusing mirrors, and beamline instrumentation at the facilities.

The increasing complexity of DOE mission-relevant materials such as superconductors, semiconductors, and magnets requires ever more sophisticated scattering techniques to extract useful knowledge and to develop new theories for the behavior of these materials. X-ray and neutron scattering probes are some of the primary tools for characterizing the atomic, electronic, and magnetic structures of materials. Additionally, neutrons play a key role in hydrogen research as they provide atomic- and molecular-level information on structure, diffusion, and interatomic interactions for hydrogen. They also allow access to the morphologies that govern useful properties in catalysts, membranes, proton conductors, and hydrogen storage materials. The activity is relevant to the behavior of matter in extreme environments, especially at high pressure

In FY 2009, neutron and x-ray scattering research will be increased to initiate activities to determine electrode and electrolyte structure in electrical energy storage devices at various states of charge and discharge, cycle life, and operating conditions ($+3,000,000). The increased neutron and x-ray fluxes and optimized beamline optics at BES user facilities, combined with specialized instrumentation, present unique and exciting opportunities for the design of an entirely new set of experiments to follow electrochemical processes in real time. Emphasis will be on using elastic and inelastic neutron scattering to determine structure and local dynamics and on neutron reflectivity to examine electrode/electrolyte interfaces. Time-resolved measurements will be used to study phase transformation kinetics in both amorphous and crystalline phases. Additional core research activities will be initiated to support scattering research for materials under extreme conditions ($+1,758,000) . Of particular interest are environments involving ultrahigh pressure for exploring novel phase and phenomena not accessible via ambient conditions. Additional funding ($+4,000,000) will support photon-based ultrafast materials science research with an emphasis on the understanding of the physics of strongly correlated systems, such as high temperature superconductors and magnetic materials with colossal magneto-resistance. The common characteristic of this class of materials is a significant interplay among the electronic-, lattice-, spin-, and/or orbital degrees of freedom, which can be probed by ultrafast techniques. Increase in this area of research will support new activities in ultrafast science at universities and DOE laboratories, including Stanford/SLAC—the home of the Linac Coherent Light Source, which is the BES centerpiece for activities in ultrafast sciences. Funding will also support mid-scale instrumentation needs including end stations at the synchrotron light sources and neutron scattering facilities ($+10,600,000). With its sensitivity to light elements, neutron scattering and instrumentation will continue to play a key role in hydrogen research ($+2,300,000). Funding for support of HFIR research and user support staff at ORNL is transferred to SNS facility operations ($-8,500,000); this funding is now part of the joint SNS-HFIR user support program. The HFIR operations budget continues to support operations of the reactor only.

	FY 2007	FY 2008	FY 2009
▪ **Electron and Scanning Probe Microscopies**	**23,021**	**23,020**	**34,496**

This activity was formerly named Structure and Composition of Materials. The activity supports basic research in condensed matter physics and materials physics using electron scattering and microscopy and scanning probe techniques, primarily at BES supported user facilities. Research includes experiments and theory to understand the atomic, electronic, and magnetic structures of materials. This activity also supports the continual development and improvement of electron scattering and scanning probe instrumentation and techniques, including ultrafast diffraction and imaging techniques. Capital equipment funding is provided for items such as new scanning probes and electron microscopes as well as ancillary equipment including high resolution detectors.

The properties of materials depend upon their structure. Performance improvements for environmentally acceptable energy generation, transmission, storage, and conversion technologies likewise depend upon the structural characteristics of advanced materials. Electron and scanning probe microscopies are some of the primary tools for characterizing the atomic, electronic, and magnetic structures of materials. The activity is relevant to hydrogen research through the structural determination of nanostructured materials for hydrogen storage and solar hydrogen generation.

In FY 2009, there is an increase to fund basic research to develop new concepts based on electron scattering and scanning probe techniques for in situ characterization of electrochemical reactions in electrical energy storage systems ($+1,500,000). The emphasis of this research will be the development of tools that will have radically improved spatial, time, and energy resolution to provide fundamental understanding of the electron and charge transfer processes and mechanisms by which ions interact with electrode materials. The main focus will be on characterization of transient nonequilibrium nanoscale structures, including adsorbed species in both vacuum and electrochemical environments, with near-atomic spatial resolution and femtosecond time scale. New research activities will also be initiated for developing ultrafast electron scattering probes as companion tools to ultrafast photon probes ($+1,000,000). Funds will also support activities in developing new experimental tools and techniques for atomic scale structural characterization, including scanning probes and electron-based scattering techniques, to further advance the nanoscale science ($+2,000,000). In addition, there are increases to support the development of advanced electron microscopy and scanning probe techniques for mid-scale instrumentation needs ($+2,000,000), and new experimental tools and techniques for atomic scale structural characterization for research related to the hydrogen economy ($+100,000), for solar energy

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

conversion ($+3,876,000) and to enhance core research in developing novel electron and scanning probes for materials characterization under extreme conditions ($+1,000,000).

	FY 2007	FY 2008	FY 2009
▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**	**7,280**	**14,680**	**8,240**

This activity supports basic research spanning the broad range of science and technology programs within the DOE 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 Hampshire, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Vermont, West Virginia, and Wyoming, along with the Commonwealth of Puerto Rico and the U.S. Virgin Islands. The research supported by EPSCoR includes materials sciences, chemical sciences, physics, energy-relevant biological sciences, geological and environmental sciences, high energy physics, nuclear physics, fusion energy sciences, advanced computing, and the basic sciences underpinning fossil energy, energy efficiency, and renewable energy.

The core activity interfaces with all other core activities within the Office of Science. It is also responsive and supports the DOE mission in the areas of energy and national security and in mitigating their associated environmental impacts.

In FY 2009, support will continue for basic research related to all DOE mission areas and to enhance collaborative efforts with DOE user facilities. The FY 2009 Request will allow EPSCOR to continue at a level consistent with the FY 2007 Appropriation and the FY 2008 Request.

The following table shows EPSCoR distribution of funds by state.

EPSCoR Distribution of Funds by State

	FY 2007	FY 2008	FY 2009
Alabama	393	264	—
Alaska	—	—	—
Arkansas	139	—	—
Delaware	629	980	980
Hawaii	—	—	—
Idaho	400	400	400
Kansas	—	—	—
Kentucky	450	650	650
Louisiana	440	440	440
Maine	450	650	650
Mississippi	—	—	—
Montana	134	131	—
Nebraska	269	140	—
Nevada	455	468	—

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
New Hampshire[a]	498	545	569
New Mexico	—	—	—
North Dakota	350	350	—
Oklahoma	713	661	681
Puerto Rico	—	—	—
Rhode Island	—	—	—
South Carolina	939	910	785
South Dakota	—	—	—
Tennessee[b]	275	275	135
Vermont	—	—	—
U.S. Virgin Islands	—	—	—
West Virginia	495	495	—
Wyoming	140	—	—
Technical Support	111	—	110
Other[c]	—	7,321	2,840
▪ **Synthesis and Processing Science**	**15,592**	**16,590**	**25,529**

This activity supports basic research to synthesize new materials with desired structure, properties, or behavior; to understand the physical phenomena that underpin materials synthesis such as diffusion, nucleation, and phase transitions; and to develop *in situ* monitoring and diagnostic capabilities. The emphasis is on the synthesis of complex thin films and nanoscale objects with atomic layer-by-layer control; the preparation techniques for pristine single crystal and bulk materials with novel physical properties; the understanding the contributions of the liquid and other precursor states to the processing of bulk nanoscale materials; and low energy processing techniques for large scale nanostructured materials. The focus on bulk synthesis and crystal and thin films growth via physical means is complementary to the Materials Chemistry and Biomolecular Materials activity, which emphasizes chemical and biomimetic routes to new materials synthesis and design. This activity includes 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 not otherwise available to academic, governmental, and industrial research communities to be used for research purposes. Capital equipment funding is provided for crystal growth apparatus, heat treatment furnaces, lasers, chemical vapor and molecular beam epitaxial processing equipment, plasma and ion sources, and deposition instruments.

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[a]Became eligible in FY 2006.
[b]Became ineligible in April 2006. Amounts shown represent continuation funds.
[c]Uncommited funds in FY 2008 and FY 2009 will be competed among all EPSCoR states.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

Synthesis and processing science is a key component in the discovery and design of a wide variety of energy relevant materials. In this regard, the activity supports the DOE's mission in the synthesis of wide bandgap semiconductors for solid state lighting; light-weight metallic alloys for efficient transportation; novel materials such as metal organic frameworks for hydrogen storage; and structural ceramics and the processing of high temperature superconductors for near zero-loss electricity transmission.

In FY 2009, there are increases to fund new basic research in applying novel design rules for synthesizing nanostructured materials ($+2,000,000) and assemblies for electrical energy storage ($+1,500,000). The emphasis of this research will be on understanding the fundamental electrochemical characteristics of the nanoscale building blocks with varying size, shape, and in confined geometry. Additional support will fund new emergent behavior research ($+1,000,000). The research activity aims at providing synthesis and processing capabilities to enable the manipulation of individual spin, charge, and atomic configurations in ways to probe the atomistic basis of the emergent behavior. Within this funding, there are increases to support the synthesis and processing science of hydrogen-related materials ($+3,000,000), and materials for solar energy conversion ($+1,439,000).

▪ **Materials Chemistry and Biomolecular Materials**	**46,439**	**43,430**	**61,310**

This activity was formerly named Materials Chemistry. The activity supports basic research in chemical and bio-inspired synthesis and discovery of new materials. In the materials chemistry area, discovery, design, and synthesis of novel materials with an emphasis on the chemistry and chemical control of structure and collective properties are supported. Major thrust areas include nanoscale chemical synthesis and assembly; solid state chemistry for controlled synthesis and tailored reactivities; novel polymeric materials; surface and interfacial chemistry including electrochemistry; and the development of new, science-driven, laboratory-based analytical tools and techniques. In the biomolecular materials area, research supported includes biomimetic and bioinspired functional materials and complex structures, and materials aspects of energy conversion processes based on principles and concepts of biology. The focus on exploratory chemical and biomolecular formation of new materials is complementary to the emphasis on bulk synthesis, crystal growth, and thin films in the Synthesis and Processing Science activity. Capital equipment funding is provided for items such as advanced nuclear magnetic resonance and magnetic resonance imaging instruments and novel atomic force microscopes.

Research supported in this activity underpins many energy-related technological areas such as batteries and fuel cells, catalysis, energy conversion and storage, friction and lubrication, high-efficiency electronic devices, hydrogen generation and storage, light-emitting materials, light-weight high-strength materials, and membranes for advanced separations.

In FY 2009, there is an increase to support new basic research for electrical energy storage ($+7,469,000). To achieve efficient electric storage with high energy and power densities, basic research into the design and synthesis of new materials and processes is needed, including investigations into new three-dimensional nanostructured architectures that can be precisely tailored for power storage in batteries and ultracapacitors. Emphasis will be on developing a predictive understanding of the role of interfaces in the electrochemical processes underpinning energy storage technologies, devising experimental strategies for "atom-by-atom" synthesis or molecular assembly of structures for new storage materials, and exploring novel concepts for electrical and electrochemical energy storage. The funding aims at accelerating the pace of advances in achieving functions such as the ability to repair or heal defects, self-regulate, self-clean, sequester impurities, and tolerate abuse, leading to radical improvements in electric energy storage performance. Additional funding is provided for new research on direct solar conversion to fuels ($+3,973,000). The emphasis will be on tailoring the absorption and charge separation via the control of photon and electron motion in materials, and to take full advantage of the nanotechnology/biotechnology revolutions to enable exquisite design of materials and the mimicking of natural function. The confluence of the emerging nanoscale hybrid materials and advances in the understanding of nature's design rules of its photosynthetic and catalytic systems opens up opportunities for combining biological and inorganic/organic components in engineered assemblies with unprecedented efficiencies for the conversion of solar photons to fuels and chemicals. Also supported are activities in developing instrumentation to measure forces, atomic configuration, and physical and chemical properties with ultrahigh sensitivity to further advance the nanoscale science ($+2,000,000). Additional funding is provided for research related to the hydrogen economy ($+2,938,000) and for developing mid-scale synthesis and characterization tools ($+1,500,000).

	FY 2007	FY 2008	FY 2009
▪ **Engineering Research**	**475**	**—**	**—**

This activity supported studies of the conduction of heat in terms of the interactions of phonons (or crystal lattice vibrations) with crystalline defects and impurities and the transfer of mass and energy in turbulent flow in geometrically constrained systems and the mechanics of nanoscale systems. In FY 2008, the remaining engineering research activities were terminated because of competing priorities.

	FY 2007	FY 2008	FY 2009
▪ **Electron-beam Microcharacterization**	**8,040**	**8,183**	**11,250**

This activity supports operation of three electron-beam microcharacterization centers, which support research on next-generation electron-beam instrumentations and operate as user facilities. These centers are: (1) the Electron Microscopy Center for Materials Research at ANL, (2) the National Center for Electron Microscopy at LBNL, and (3) the Shared Research Equipment Program at ORNL. These centers contain various specialized instruments to provide information on the structure, chemical composition, and properties of materials from the atomic level up using direct imaging, diffraction, spectroscopy, and other techniques based primarily on electron scattering. Atomic arrangements, local bonding, defects, interfaces and boundaries, chemical segregation and gradients, phase separation, and surface phenomena are all aspects of the nanoscale and atomic structure of materials, which ultimately controls the mechanical, thermal, electrical, optical, magnetic, and many other properties and behaviors. Electron probes are valuable 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 ideal cases, just one. The use of charged particles allows electromagnetic control and lensing of electron beams, resulting in spatial resolution that can approach single atomic separations or better. Capital equipment funding 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

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

probe microscopes, and/or auxiliary tools such as spectrometers, detectors, and advanced sample preparation equipment.

In FY 2009, additional funds are provided for enhanced user support, scientific research of staff scientists, and development of new instruments or techniques ($+3,067,000). This includes staffing, maintenance, and other operational support for the Transmission Electron Aberration Corrected Microscope (TEAM), which will be in operation as part of the National Center for Electron Microscopy at LBNL.

	FY 2007	FY 2008	FY 2009
▪ **Accelerator and Detector Research**	**1,476**	**1,833**	**9,120**

This activity supports basic research in accelerator physics and x-ray and neutron detectors. Research includes studies of ultra-high brightness electron beams to drive self amplified spontaneous emission free electron lasers, such as the Linac Coherent Light Source (LCLS); collective electron effects, such as micro-bunch instabilities from coherent synchrotron and edge radiation; beam bunching techniques, such as magnetic compression or velocity bunching; fast instruments to determine the structure of femtosecond electron bunches; and detectors capable of acquiring data at very high collection rates.

This activity interacts with BES scientific research that employs synchrotron and neutron sources. It also interacts with other DOE offices, especially in the funding of capabilities whose cost and complexity require shared support. Research at the Accelerator Test Facility at Brookhaven National Laboratory is jointly funded by the High Energy Physics and BES programs. There is also planned collaboration with the National Science Foundation (NSF) on Energy Recovery Linac (ERL) research. There is a coordinated effort between DOE and NSF to facilitate x-ray detector development. There are ongoing industrial interactions through DOE Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) program awards for the development of x-ray detectors and advanced accelerator technology.

Additional funds provided in FY 2009 will increase selected ongoing activities in accelerator-based research activities ($+7,287,000). These include the physics of gain mechanisms in free-electron lasers (FELs), rapid electron bunch diagnostics, advanced x-ray and neutron detectors, H^- high intensity sources, and accelerator modeling. These projects are essential to the efficient operation and use of present BES x-ray and neutron scattering facilities and to the design of future facilities.

	FY 2007	FY 2008	FY 2009
▪ **Nanoscale Science Research Centers**	**500**	**500**	**—**

Funding for Other Project Costs for Nanoscale Science Research Centers has been completed.

	FY 2007	FY 2008	FY 2009
▪ **Spallation Neutron Source Instrumentation I (SING I)**	**10,500**	**11,856**	**12,000**

Funds are provided to continue a Major Item of Equipment with a total estimated cost and total project cost of $68,500,000 for five instruments for the Spallation Neutron Source (SNS). The instrument concepts for the project were competitively selected using a peer review process, and the instruments will be installed at the SNS on a phased schedule between FY 2008–2011.

	FY 2007	FY 2008	FY 2009
▪ **Spallation Neutron Source Instrumentation II (SING II)**	**500**	**6,000**	**7,000**

Funds are provided for a Major Item of Equipment with a Total Project Cost in the range of $40,000,000 to $60,000,000 for four instruments to be installed at the SNS. The instrument concepts

	FY 2007	FY 2008	FY 2009
(dollars in thousands)			

for the project have been competitively selected using a peer review process. The project is 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 Independent Project Reviews. It is anticipated that these instruments will be installed at the SNS on a phased schedule beginning in about FY 2011. The SING II instruments are in addition to the five instruments to be provided by the SING I MIE.

The Alternative Selection and Cost Range (CD-1) was approved on September 27, 2007, with an estimated cost range of $40,000,000 to $60,000,000. The baseline TPC will be approved at Approve Performance Baseline, CD-2 for each of the four instruments. The FY 2009 Budget Request is for engineering design only. Engineering design may include limited fabrication and testing of design concepts. Funds for full fabrication will be requested after approval of the Performance Baseline, CD-2.

	FY 2007	FY 2008	FY 2009
▪ **Linac Coherent Light Source Ultrafast Science Instruments (LUSI)**	**2,000**	**6,000**	**15,000**

Funds are provided for a Major Item of Equipment with a total project cost in the range of $50,000,000 to $60,000,000 for three instruments for the Linac Coherent Light Source (LCLS) that will be installed after the LCLS line item project is completed in FY 2010. The technical concepts for the three instruments have been developed in consultation with the scientific community through a series of workshops, conferences, and focused review committees. Instrument designs for the LUSI project have been competitively selected using a peer review process. The project is managed by the Stanford Linear Accelerator Center. The TEC will be narrowed to a cost and schedule performance baseline following completion of Title I design and Independent Project Reviews. It is anticipated that these three instruments will be installed at the LCLS on a phased schedule between FY 2010–2012.

The Alternative Selection and Cost Range (CD-1) was approved on September 27, 2007, with an estimated cost range of $50,000,000 to $60,000,000. The baseline TPC will be approved at Approve Performance Baseline, CD-2. The FY 2009 Budget Request is for engineering design only. Engineering design may include limited fabrication and testing of design concepts. Funds for full fabrication will be requested after approval of the Performance Baseline, CD-2.

	FY 2007	FY 2008	FY 2009
▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	**5,508**	**6,687**	**—**

Funding for the Transmission Electron Aberration Corrected Microscope (TEAM) Major Item of Equipment is completed in FY 2008.

	FY 2007	FY 2008	FY 2009
▪ **General Plant Projects (GPP)**	**300**	**—**	**—**

GPP funding supports minor new construction, other capital alterations and additions, and improvements to land, buildings, and utility systems. 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. In FY 2009 GPP funds are transferred to the Science Laboratories Infrastructure (SLI) program to support the SC Infrastructure Modernization Initiative.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Facilities Operations	**614,231**	**645,869**	**719,247**

This activity supports the operation of four synchrotron radiation light sources,

- the Advanced Light Source (ALS) at LBNL,
- the Advanced Photon Source (APS) at ANL,
- the National Synchrotron Light Source (NSLS) at BNL, and
- the Stanford Synchrotron Radiation Laboratory (SSRL) at SLAC;

three neutron scattering facilities,

- the High Intensity Flux Reactor (HFIR) at ORNL,
- the Manuel Lujan Jr. Neutron Scattering Center (Lujan Center) at LANL, and
- the Spallation Neutron Source (SNS) at ORNL;

five Nanoscale Science Research Centers (NSRCs),

- the Center for Nanophase Materials Sciences at ORNL,
- the Molecular Foundry at LBNL,
- the Center for Integrated Nanotechnologies at SNL/LANL,
- the Center for Nanoscale Materials at ANL, and
- the Center for Functional Nanomaterials at BNL;

and one linear accelerator for a project under construction,

- the Linac Coherent Light Source (LCLS) linac at SLAC.

The BES scientific user facilities, which include light sources, neutron sources, and nanoscience centers, serve researchers from universities, national laboratories, and industry, providing specialized instrumentation and expertise that enables scientific users to carry out experiments or develop theories that could not be done by individual investigators at their home institutions. For approved, peer-reviewed projects, operating time is available without charge to those scientists who intend to publish their results in the open literature. More than 10,000 scientists are users of BES facilities annually. The number of users for the synchrotron radiation sources and neutron scattering facilities are shown in the table below, and a table of the number of users for all BES facilities, FY 2000–2007, is provided at: http://www.sc.doe.gov/bes/users.htm. The synchrotron light sources, producing mostly soft and hard x-rays, examine the fundamental parameters used to perceive the physical world (energy, momentum, position, and time) using the techniques of spectroscopy, scattering, and imaging applied over various time scales. Neutron sources take advantage of neutrons' electrical neutrality and special magnetic properties to probe atoms and molecules, and their assembly into materials. The suite of Nanoscale Science Research Centers provides the ability to fabricate complex nanostructures using chemical, biological, and other synthesis techniques, to characterize them, to assemble them, and to integrate them into devices. The FY 2008 budget allocation has led to termination of a facility and the remaining BES operating facilities operations will be nearly flat funded with FY 2007. The impact of the flat funding of the x-ray and neutron scattering facilities is likely to result in reduced hours of operation at these facilities by as much as 20%. This reduction in hours of operation will permit the remaining facilities to resume maintenance activities and upgrades—which have been deferred since FY 2006. In FY 2009, operation of these scientific user facilities is funded at a level that will permit optimal service to users. FY 2009 marks the first year of sole BES support for SLAC linac operations, which transitioned from HEP to BES funding in FY 2006 through FY 2008.

Additional funds are provided in FY 2009 for full operation of the SLAC linac and for enhanced beamline capabilities and user support at the new SNS and HFIR neutron beamlines. The light source budget increases reflect the increase in the number of operating beamlines as well as user support at the facilities. Increases in the NSRC budgets reflect full functionality and staffing of the five NSRCs, Small variations in the operations allocations across the five NSRCs reflect differing facility needs and priorities as well as the results of initial operations reviews of the four facilities in FY 2007. Other project costs are provided for two facilities that are under construction and are described elsewhere in this budget: the Linac Coherent Light Source (LCLS) at SLAC and the National Synchrotron Light Source II at BNL. The Intense Pulsed Neutron Source is closed as a result of competing priorities, and funds are provided to begin the decommissioning of the target assembly.

The facility operations budget request 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. 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 is provided below. Of the total FY 2009 operations budget, $617,788,000 is provided for operating expenses, $67,369,000 is provided for capital equipment, $32,643,000 is provided for AIP, and $1,447,000 is provided for GPP.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Facilities			
Advanced Light Source, LBNL	48,797	47,367	51,049
Advanced Photon Source, ANL	105,000	105,000	116,514
National Synchrotron Light Source, BNL	36,900	36,900	40,149
National Synchrotron Light Source-II, BNL	22,000	20,000	10,000
Stanford Synchrotron Radiation Laboratory, SLAC	30,725	30,825	33,028
High Flux Isotope Reactor, ORNL	55,705	54,511	58,780
Intense Pulsed Neutron Source, ANL	15,500	8,000	4,000
Manuel Lujan, Jr. Neutron Scattering Center, LANL	10,500	10,500	11,155
Spallation Neutron Source, ORNL	165,500	164,640	177,640
Center for Nanophase Materials Sciences, ORNL	18,115	18,000	19,975
Center for Integrated Nanotechnologies, SNL/LANL	17,864	18,100	20,100
Molecular Foundry, LBNL	19,056	18,250	20,150
Center for Nanoscale Materials, ANL	18,019	18,526	20,857
Center for Functional Nanomaterials, BNL	—	18,250	20,150
Linac Coherent Light Source (LCLS), SLAC	13,000	15,500	19,000
Linac for LCLS, SLAC	37,550	61,500	96,700

The following table shows the hours of operation and numbers of users for the major scientific user facilities—the synchrotron radiation sources and the neutron scattering facilities. 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. Scheduled hours for FY 2007 represent the actual number of hours delivered to users. NSLS and SSRL delivered unscheduled hours to users in FY 2007 resulting in a total greater than Optimal Hours estimates.

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Estimate
All Facilities			
Optimal Hours	29,070	35,800	34,000
Scheduled Hours	27,551	28,580	31,800
Unscheduled Downtime	6%	<10%	<10%
Number of Users	9,079	8,510	9,800

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Estimate
Advanced Light Source			
Optimal Hours	4,200	5,600	5,600
Scheduled Hours	3,916	5,000	5,400
Unscheduled Downtime	12%	<10%	<10%
Number of Users	1,748	1,900	2,100
Advanced Photon Source			
Optimal Hours	5,000	5,000	5,000
Scheduled Hours	4,751	4,380	4,800
Unscheduled Downtime	2%	<10%	<10%
Number of Users	3,420	3,000	3,500
National Synchrotron Light Source			
Optimal Hours	5,400	5,400	5,400
Scheduled Hours	5,971	4,900	5,200
Unscheduled Downtime	3%	<10%	<10%
Number of Users	2,219	2,000	2,100
Stanford Synchrotron Radiation Laboratory			
Optimal Hours	5,400	5,400	5,400
Scheduled Hours	5,424	4,500	5,000
Unscheduled Downtime	2%	<10%	<10%
Number of Users	1,151	1,100	1,300
High Flux Isotope Reactor			
Optimal Hours	1,200	4,500	4,500
Scheduled Hours	1,178	3,100	3,900
Unscheduled Downtime	0%	<10%	<10%
Number of Users	72	130	450

(dollars in thousands)

	FY 2007	FY 2008	FY 2009

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Estimate
Intense Pulsed Neutron Source			
Optimal Hours	3,600	3,600	—
Scheduled Hours	2,965	1,000	—
Unscheduled Downtime	3%	<10%	—
Number of Users	173	80	—
Manuel Lujan, Jr. Neutron Scattering Center			
Optimal Hours	3,600	3,600	3,600
Scheduled Hours	2,806	3,000	3,500
Unscheduled Downtime	<19%	<10%	<10%
Number of Users	272	260	280
Spallation Neutron Source			
Optimal Hours	670	2,700	4,500
Scheduled Hours	540	2,700	4,000
Unscheduled Downtime	19%	<10%	<10%
Number of Users	24	40	70

	FY 2007	FY 2008	FY 2009
SBIR/STTR	**—**	**24,340**	**26,939**

In FY 2007, $20,699,000 and $2,484,000 were transferred to the SBIR and STTR programs, respectively. The FY 2008 and FY 2009 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

	FY 2007	FY 2008	FY 2009
Total, Materials Sciences and Engineering	**879,323**	**954,060**	**1,125,579**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Experimental Condensed Matter Physics	
Increases are provided for mid-scale instrumentation ($+2,500,000); hydrogen economy ($+3,350,000); and solar energy conversion ($+3,939,000).	+9,789

	FY 2009 vs. FY 2008 ($000)
Theoretical Condensed Matter Physics	
Increases are provided for emergent behavior ($+1,500,000); electric energy storage ($+2,000,000); hydrogen economy ($+2,938,000); solar energy conversion ($+1,920,000); and nanoscale phenomena for energy applications ($+2,000,000).	+10,358
Mechanical Behavior and Radiation Effects	
Increases are provided to enhance core research in high-temperature mechanical behavior and radiation effects in materials under extreme environments ($+1,000,000) and to fund new basic research to develop a new generation of robust materials for utilization in high-temperature and irradiation-probe environments for advanced nuclear energy systems ($+8,492,000).	+9,492
Physical Behavior of Materials	
Increases are provided for new research to develop new concepts underpinning electrolyte development ($+1,500,000); hydrogen economy ($+700,000); solar energy conversion ($+3,379,000); and nanoscale behavior in materials for energy applications ($+2,000,000).	+7,579
Neutron and X-ray Scattering	
Decrease is due to transfer of support for the HFIR user program to the SNS facility operations budget; the SNS and HFIR user programs will be operated jointly ($-8,500,000). Increases are provided to determine electrode and electrolyte structure in electrical energy storage devices at various states of charge and discharge, cycle life, and operating conditions and to develop new concepts using x-ray and neutron scattering tools for in-situ characterization of electrochemical reactions in electrical energy storage systems ($+3,000,000); mid-scale instrumentation ($+10,600,000); ultrafast science ($+4,000,000); hydrogen economy ($+2,300,000); and support scattering research for materials under extreme conditions ($+1,758,000).	+13,158
Electron and Scanning Probe Microscopies	
Increases are provided to support new research to fund basic research to develop new concepts based on electron scattering and scanning probe techniques for in-situ characterization of electrochemical reactions in electrical energy storage systems ($+1,500,000); ultrafast science ($+1,000,000); mid-scale instrumentation ($+2,000,000); hydrogen economy ($+100,000); solar energy conversion ($+3,876,000); nanoscale electrons and scanning probes development ($+2,000,000); and enhance core research in developing novel electron and scanning probes for materials characterization under extreme conditions ($+1,000,000).	+11,476
Experimental Program to Stimulate Competitive Research (EPSCoR)	
The FY 2009 Request will allow EPSCoR to continue at a level consistent with the FY 2007 Appropriation and the FY 2008 Request.	-6,440

	FY 2009 vs. FY 2008 ($000)
Synthesis and Processing Science	
Increases are provided to fund new basic research in applying novel design rules for synthesizing nanostructured materials and assemblies for electrical energy storage ($+1,500,000); emergent behavior ($+1,000,000); hydrogen economy ($+3,000,000); solar energy conversion ($+1,439,000); and novel design in nanoscale synthesis ($+2,000,000).	+8,939
Materials Chemistry and Biomolecular Materials	
Increases is provided to support new basic research for electrical energy storage to further expand the materials design and synthesis efforts in developing novel electrolytes, nanostructured electrode architectures, and new electrochemical couples ($+7,469,000); mid-scale instrumentation ($+1,500,000); hydrogen economy ($+2,938,000); solar energy conversion ($+3,973,000); and nanoscale tools for developing mid-scale synthesis and characterization ($+2,000,000).	+17,880
Electron-beam Microcharacterization	
Increase is provided for enhanced user operations within the current operating schedules of the facilities, scientific research of facility staff, and development of new instruments or techniques at the facilities.	+3,067
Accelerator and Detector Research	
Increase is provided to expand the portfolio of accelerator and detector research projects, including the physics of gain mechanisms in free-electron lasers (FELs), rapid electron bunch diagnostics, advanced x-ray and neutron detectors, H- high intensity sources and accelerator modeling.	+7,287
Nanoscale Science Research Centers Other Project Costs	
Decrease in funding due to completion of the Nanoscale Science Research Centers.	-500
Spallation Neutron Source Instrumentation I	
Scheduled increase for the Major Item of Equipment which will provide instrumentation for the Spallation Neutron Source.	+144
Spallation Neutron Source Instrumentation II	
Scheduled increase for the Major Item of Equipment which will provide instrumentation for the Spallation Neutron Source.	+1,000
Linac Coherent Light Source Ultrafast Science Instruments (LUSI)	
Scheduled increase for the Major Item of Equipment for the Linac Coherent Light Source Ultrafast Science Instruments.	+9,000

	FY 2009 vs. FY 2008 ($000)
Transmission Electron Aberration Corrected Microscope (TEAM)	
Decrease for the Major Item of Equipment for the Transmission Electron Aberration Corrected Microscope due to the completion of the project.	-6,687
Total, Materials Sciences and Engineering Research	**+95,542**
Facilities Operations	
▪ **Operation of National User Facilities**	
Increase for the Advanced Light Source to support accelerator operations and users.	+3,682
Increase for Advanced Photon Source to support accelerator operations and users.	+11,514
Increase for National Synchrotron Light Source to support accelerator operations and users.	+3,249
Decrease for National Synchrotron Light Source-II – Other Project Costs per the project schedule.	-10,000
Increase for the Stanford Synchrotron Radiation Laboratory to support accelerator operations and users.	+2,203
Increase for High Flux Isotope Reactor to support reactor operations.	+4,269
Decrease for the Intense Pulsed Neutron Source to maintain the facility in a safe storage condition.	-4,000
Increase for the Manuel Lujan, Jr., Neutron Scattering Center to support target operations and users at approximately the FY 2008 level.	+655
Increase for Spallation Neutron Source. The increase includes an increase for operations ($+4,500,000) and also the transfer of funds previously funded in X-ray and Neutron Scattering for the now joint SNS-HFIR user program. ($+8,500,000).	+13,000
Increase for the Center for Nanophase Materials to support operations and users.	+1,975
Increase for the Center for Integrated Nanotechnologies to support operations and users.	+2,000
Increase for the Molecular Foundry to support operations and users.	+1,900
Increase for the Center to Nanoscale Materials to support operations and users.	+2,331
Increase for the Center for Functional Nanomaterials to support operations and users.	+1,900
Increase for Linac Coherent Light Source Other Project Costs per the project schedule ($+1,500,000) and increase to begin operations of the LCLS portion of the Linac that has been commissioned ($+2,000,000).	+3,500

	FY 2009 vs. FY 2008 ($000)
Increase for Stanford Linear Accelerator Center for the first year of full BES support of the linac operations.	+35,200
Total, Facilities Operations	**+73,378**
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in total operating expense.	+2,599
Total Funding Change, Materials Sciences and Engineering	**+171,519**

Chemical Sciences, Geosciences, and Energy Biosciences

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Chemical Sciences, Geosciences, and Energy Biosciences			
Chemical Sciences, Geosciences, and Energy Biosciences Research	209,380	209,905	289,513
Facilities Operations	7,648	7,000	—
SBIR/STTR	—	5,672	7,600
Total, Chemical Sciences, Geosciences, and Energy Biosciences	217,028	222,577	297,113

Description

This subprogram supports experimental and theoretical research to provide fundamental understanding of chemical transformations and energy flow in systems relevant to DOE missions. This knowledge serves as a basis for the development of new processes for the generation, storage, and use of energy and for mitigation of the environmental impacts of energy use.

In fundamental interactions, basic research is supported in atomic, molecular, and optical sciences; gas-phase chemical physics; ultrafast chemical science; and condensed phase and interfacial molecular science. Emphasis is placed on structural and dynamical studies of atoms, molecules, and nanostructures, and the description of their interactions in full quantum detail, with the aim of providing a complete understanding of reactive chemistry in the gas phase, condensed phase, and at interfaces. Novel sources of photons, electrons, and ions are used to probe and control atomic, molecular, and nanoscale matter. Ultrafast optical and x-ray techniques are developed and used to study chemical dynamics. There is a focus on cooperative phenomena in complex chemical systems, such as the effect of solvation on chemical structure, reactivity, and transport and the coupling of complex gas-phase chemistry with turbulent flow in combustion.

In photochemistry and biochemistry, including solar photochemistry, photosynthetic systems, and physical biosciences, research is supported on the molecular mechanisms involved in the capture of light energy and its conversion into chemical and electrical energy through biological and chemical pathways. Natural photosynthetic systems are studied to create robust artificial and bio-hybrid systems that exhibit the biological traits of self assembly, regulation, and self repair. Complementary research encompasses organic and inorganic photochemistry, photo-induced electron and energy transfer, photoelectrochemistry, and molecular assemblies for artificial photosynthesis. Inorganic and organic photochemical studies provide information on new chromophores, donor-acceptor complexes, and multi-electron photocatalytic cycles. Photoelectrochemical conversion is explored in studies of nanostructured semiconductors. Biological energy transduction systems are investigated, with an emphasis on the coupling of plant development and microbial biochemistry with the experimental and computational tools of the physical sciences.

In chemical transformations, the themes are characterization, control, and optimization of chemical transformations, including efforts in catalysis science; separations and analytical science, actinide chemistry, and geosciences. Catalysis science underpins the design of new catalytic methods for the clean and efficient production of fuels and chemicals and emphasizes inorganic and organic complexes; interfacial chemistry; nanostructured and supramolecular catalysts, photocatalysis and electrochemistry, and bio-inspired catalytic processes. Heavy element chemistry focuses on the spectroscopy, bonding, and reactivity of actinides and fission products; complementary research on chemical separations focuses on the use of nanoscale membranes and the development of novel metal-adduct complexes. Chemical analysis research emphasizes laser-based and ionization techniques for molecular detection, particularly the development of chemical imaging techniques. Geosciences research covers analytical and physical geochemistry, rock-fluid interactions, and flow/transport phenomena; this research provides a fundamental basis for understanding the environmental contaminant fate and transport and for predicting the performance of repositories for radioactive waste or carbon dioxide sequestration.

Selected FY 2007 Research Accomplishments

- *Ultrafast laser probes reveal unexpected quantum behavior in nature's photosynthetic apparatus.* Evolutionary development over 3 billion years has allowed nature to perfect the design rules for converting sunlight into chemical energy. The photosynthetic apparatus allows plants to absorb sunlight, transform its energy into reactive electrons, and then transfer the electrons to molecular reaction centers for conversion into chemical energy—with nearly 100% efficiency. Researchers have found that the speed of energy transfer is the key to this efficiency and are now using laser and x-ray techniques to probe the electron transfer mechanism on an ultrafast time scale (10^{-15} seconds). A wavelike energy transfer from the photon absorption site to the first electron transfer site is followed by a rapid "hand-off" of the electron from one molecule to another until the reaction center is reached. This result is surprising—this type of coherent energy transfer, which is uniquely quantum mechanical, was not anticipated in such a complex molecular system—and reveals yet another nuance in the mechanism of photosynthesis.
- *Artificial systems to create chemical fuels from sunlight and water*. Light-driven splitting of water to form molecular hydrogen and oxygen is a complex process that requires the net transfer of several electrons: two electrons to make hydrogen and four electrons to make oxygen. Inspired by improved understanding of the structure and function of the natural photosynthetic reaction center, researchers have created molecular assemblies with novel architectures that gather electrons in close proximity when illuminated by sunlight and that catalyze multi-electron transfer with several metal atoms. One particularly effective artificial assembly that produces hydrogen gas contains a dimer of two ruthenium atoms. Other ruthenium complexes, in which the metal atoms are arranged with exact spacing, catalyze the extraction of the four electrons to evolve oxygen with a high degree of stability. In order to make a durable artificial system, however, positively charged protons must be moved at the same time to compensate for the movement of negatively charged electrons. In both the natural and artificial systems, a water molecule that is precisely positioned by the calcium atom can better release a proton in conjunction with oxygen evolution. These new assemblies catalyze several key steps in water splitting and provide guidance for the synthesis of more effective and durable systems that produce fuel from water and sunlight.
- *Advanced probes of the complex chemistry of combustion*. Efficient combustion of hydrocarbon fuels maximizes energy output while minimizing formation and release of unwanted emissions such as fine particles of carbon soot. Recently, an integrated theoretical and experimental effort has clarified the basic chemical reactions that transform fuels into small aromatic compounds—the initial, critical step in soot particle formation. Using quantum chemistry and reaction rate theory, reaction rates and product yields were calculated for the many different aromatic products of a prototypical reaction. Complementary experiments at the Advanced Light Source employing a novel kinetics reactor coupled with vacuum ultraviolet (VUV) photoionization and mass spectrometric detection have provided the first direct, time-resolved measurements of the isomer distribution of the products

formed in the propargyl association reaction. The experimental and computational results are in good agreement and set the stage for further targeted studies of other reactions that are critical to incipient soot formation.

- *Remarkable new insights into chemical bonding.* The search for model transition-metal oxide catalysts has led to the discovery of a new kind of bonding involving the 5d atomic orbitals on a triangular shaped cluster of tantalum atoms. The 5d orbitals combine to form a previously unknown type of delocalized molecular bond that may be important for other transition metal compounds. Using exquisitely sensitive experimental tools, coupled with computational chemistry, the discovery of subtle differences in bonding was recognized as the origin of different reaction pathways of thorium and uranium ions as they react to form organometallic complexes in solution. Such insights also led to the design of a new tweezer-like molecule, which has now been synthesized and shown to achieve selective separation chemistry of radioactive species.
- *New chemical imaging capability using neutron scattering.* Researchers are using neutron scattering techniques to probe chemically modified interfaces that are important in geochemistry, biochemistry, catalysis science, and separations membranes. BASIS, a newly commissioned backscattering spectrometer end station at the Spallation Neutron Source, takes advantage of increased flux and a significant increase in energy resolution to investigate oxide hydration layers and probe the dynamics of the interactions of water with metals, minerals, and other chemically important substrates. Coupling these observations with computational molecular dynamics simulations recently revealed new dynamical behavior of water in hydration layers on metals and minerals. Neutron scattering is also being used to probe the dynamics of organic molecules tethered to silica surfaces and to probe the differences in interfacial interactions between hydrocarbons and surfaces.

Detailed Program Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Chemical Sciences, Geosciences, and Energy Biosciences Research	**209,380**	**209,905**	**289,513**
▪ **Atomic, Molecular, and Optical Science**	**18,112**	**18,112**	**23,659**

This activity supports theory and experiments to understand structural and dynamical properties of atoms, molecules, and nanostructures. The research emphasizes the fundamental interactions of these systems with photons and electrons to characterize and control their behavior. These efforts aim to develop accurate quantum mechanical descriptions of properties and dynamical processes of atoms, molecules, and nanoscale matter. The study of energy transfer within isolated molecules provides the foundation for understanding chemical reactivity, i.e., the process of energy transfer to ultimately make and break chemical bonds. Topics include the development and application of novel, ultrafast optical probes of matter, particularly x-ray sources; the interactions of atoms and molecules with intense electromagnetic fields; and studies of collisions and many-body cooperative interactions of atomic and molecular systems, including ultracold atomic and molecular gases. Capital equipment funding is provided for items such as lasers and optical equipment, unique ion sources or traps, position-sensitive and solid-state detectors, control and data processing electronics, and computational resources.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

The knowledge and techniques produced by this activity form a science base that underpins several aspects of the DOE mission. New methods for using photons, electrons, and ions to probe matter lead to more effective use of BES synchrotron, nanoscience, and microcharacterization facilities. Similarly, the study of formation and evolution of energized states in atoms, molecules, and nanostructures provides a fundamental basis for understanding elementary processes in solar energy conversion and radiation-induced chemistry. The activity also supports research on the fundamental interactions of atoms, molecules, and ions of importance to fusion and fission energy research.

In FY 2009, emphasis will continue on the development of new ultrafast x-ray and optical probes; theories for the interpretation of ultrafast measurements; use of optical fields to control quantum mechanical processes; and atomic and molecular interactions at ultracold temperatures. In FY 2009, there are increases for coherent control of quantum systems ($+1,047,000), ultrafast science ($+2,000,000), chemical imaging ($+500,000), mid-scale instrumentation ($+500,000), and nanoscale science associated with complex systems ($+1,500,000).

▪ **Chemical Physics Research**	**33,877**	**34,777**	**52,764**

This activity supports experimental and theoretical investigations in the gas phase, in condensed phases, and at interfaces aimed at elucidating the chemical transformations and physical interactions that govern combustion; surface reactivity; and solute/solvent structure, reactivity, and transport. The activity has a gas-phase chemical physics portion and a condensed phase and interfacial molecular science portion. The gas-phase chemical physics portion emphasizes studies of the dynamics and rates of chemical reactions at energies characteristic of combustion and the chemical and physical properties of key combustion intermediates; the goal is development of validated theories and computational tools for predicting chemical reaction rates for use in combustion models and experimental tools for validating these models. Combustion models using this input are developed that incorporate complex chemistry with the turbulent flow and energy transport characteristics of real combustion processes. This activity includes support for the Combustion Research Facility (CRF), a multi-investigator research laboratory for the study of combustion science and technology that emphasizes experiment and theory in chemical dynamics, chemical kinetics, combustion modeling, and diagnostic development. The condensed-phase and interfacial chemical physics portion of this activity emphasizes molecular understanding of chemical, physical, and electron-driven processes in aqueous media and at interfaces. Studies of reaction dynamics at well-characterized metal or metal-oxide surfaces lead to the development of theories on the molecular origins of surface-mediated catalysis and heterogeneous chemistry. Research confronts the transition from detailed, molecular-scale understanding to cooperative and collective phenomena in complex systems. Capital equipment funding is provided for items such as lasers and optical equipment, novel position-sensitive and temporal detectors, specialized vacuum chambers for gas-phase and surface experiments, spectrometers, and computational resources.

The gas-phase portion of this activity contributes strongly to the DOE mission in the area of the efficient and clean combustion of fuels. The chemical complexity of combustion has provided an impressive challenge to predictive modeling. Truly predictive combustion models enable the design of new combustion devices (such as internal combustion engines, burners, and turbines) with maximum energy efficiency and minimal environmental consequences. In transportation, the changing composition of fuels, from those derived from light, sweet crude oil to biofuels and fuels

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

from alternative fossil feedstocks, puts increasing emphasis on the need for science-based design of modern engines. The condensed-phase and interfacial portion of this activity impacts a variety of mission areas by providing a fundamental basis for understanding chemical reactivity in complex systems, such as those encountered in catalysis and environmental processes. Surface-mediated chemistry research in this activity complements more directed efforts in heterogeneous catalysis. Condensed-phase and interfacial chemical physics research on dissolution, solvation, nucleation, separation, and reaction provides important fundamental knowledge relevant to the environmental contaminant transport in mineral and aqueous environments. Fundamental studies of reactive processes driven by radiolysis in condensed phases and at interfaces provide improved understanding of radiolysis effects in nuclear fuel and waste environments.

In FY 2009, there will be an increased focus on experimental and theoretical research aimed at developing predictive models for clean and efficient combustion of biofuels and alternative fossil fuels in modern engines. Elucidating the reactivity of individual molecular sites in interfacial processes and the effects of cooperative phenomena on chemical reactivity in the condensed phase will also receive emphasis. In FY 2009, there are increases for gas-phase chemical physics focused on combustion of alternative transportation fuels ($+392,000); ultrafast science ($+1,000,000); chemical imaging ($+750,000); mid-scale instrumentation ($+500,000); emergent behavior in condensed phase systems ($+1,000,000); nanoscale interfacial systems ($+1,500,000); solar energy conversion ($+1,697,000); and interfacial chemical physics relevant to electrical energy storage, including studies of electrode-electrolyte interfaces, charge transfer, and transport ($+3,969,000). Also in FY 2009, there is an increase due to the transfer of the Combustion Research Facility from Facility Operations to Chemical Physics Research ($+7,179,000). The CRF has been transferred to the research portion of the budget in recognition of its role as a research operation with visitor access via collaboration with staff scientists rather than a user facility.

▪ **Solar Photochemistry**	**30,603**	**30,603**	**39,569**

This activity was formerly named Photochemistry and Radiation Research. The activity supports molecular-level research on solar energy capture and conversion in the condensed phase and at interfaces. These investigations of solar photochemical energy conversion focus on the elementary steps of light absorption, electrical charge generation, and charge transport within a number of chemical systems, including those with significant nanostructured composition. Supported research areas include organic and inorganic photochemistry and photocatalysis, photoinduced electron and energy transfer in the condensed phase and across interfaces, photoelectrochemistry, and artificial assemblies for charge separation and transport that mimic natural photosynthetic systems. This activity, with its integration of physical and synthetic scientists devoted to solar photochemistry, is unique to DOE. Capital equipment funding is provided for items such as ultrafast laser systems, scanning tunneling microscopes, fast Fourier transform infrared and Raman spectrometers, and computational resources.

Solar photochemical energy conversion is an important option for generating electricity and chemical fuels and therefore plays a vital role in the DOE's development of solar energy as a viable component of the Nation's energy supply. Photoelectrochemistry provides an alternative to semiconductor photovoltaic cells for electricity generation from sunlight using closed, renewable energy cycles. Solar photocatalysis, achieved by coupling artificial photosynthetic systems for light harvesting and charge transport with the appropriate electrochemistry, provides a direct route to the

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

generation of fuels such as hydrogen, methane, and complex hydrocarbons. Fundamental concepts derived from studying highly efficient excited-state charge separation and transport in molecular assemblies is also applicable to the future molecular optoelectronic device development.

In FY 2009, continued emphasis will be placed on studies of semiconductor/polymer interfaces, multiple charge generation within semiconductor nanoparticles, and dye-sensitized solar cells. Research will be extended in inorganic/organic donor-acceptor molecular assemblies and in the use of nanoscale materials in solar photocatalytic generation of chemical fuels. In FY 2009, there are increases for ultrafast science ($+1,000,000); solar energy conversion, including solar photo-electrochemistry and solar photoconversion using solid-state organic systems ($+4,686,000); research related to the hydrogen economy, including solar hydrogen production ($+1,280,000); and enhanced experimental and theoretical studies of photo-electrochemical and interfacial charge transfer processes in electrical energy storage ($+2,000,000).

	FY 2007	FY 2008	FY 2009
▪ **Photosynthetic Systems**	**14,750**	**14,750**	**19,926**

This activity was formerly named Molecular Mechanisms of Natural Solar Energy Conversion. The activity supports fundamental research on the biological conversion of solar energy to chemically stored forms of energy. Topics of study include light harvesting, exciton transfer, charge separation, transfer of reductant to carbon dioxide, as well as the biochemistry of carbon fixation and carbon storage. Accentuated areas are those involving strong intersection between biological sciences and energy-relevant chemical sciences and physics, such as in self-assembly of nanoscale components, efficient photon capture and charge separation, predictive design of catalysts, and self-regulating/repairing systems. Capital equipment funding is provided for items such as ultrafast lasers, high-speed detectors, spectrometers, environmentally controlled chambers, high-throughput robotic systems, and computational resources.

The impact of research in this activity is to uncover the underlying structure-function relationships and to probe dynamical processes in natural photosynthetic systems to guide the development of robust artificial and bio-hybrid systems for conversion of solar energy into electricity or chemical fuels. The ultimate goal is the development of bio-hybrid systems in which the best features from nature are selectively used while the shortcomings of biology are bypassed. Achieving this goal would impact DOE’s efforts to develop solar energy as an efficient, renewable energy source.

In FY 2009, research will emphasize understanding and control of the weak intermolecular forces governing molecular assembly in photosynthetic systems; understanding the biological machinery for cofactor insertion into proteins and protein subunit assemblies; adapting combinatorial, directed-evolution, and high-throughput screening methods to enhance fuel production in photosynthetic systems; characterizing the structural and mechanistic features of new photosynthetic complexes; and determining the physical and chemical rules that underlie biological mechanisms of repair and photo-protection. In FY 2009, there are increases for chemical imaging ($+750,000); emergent behavior in biological systems ($+500,000); and solar energy conversion, including research on biological and bio-hybrid systems and enhanced efforts in understanding defect tolerance and self-repair in natural photosynthetic systems ($+3,926,000).

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
▪ **Physical Biosciences**	**14,175**	**14,175**	**15,675**

This activity was formerly named Metabolic Regulation of Energy Production. The activity combines experimental and computational tools from the physical sciences with biochemistry and molecular biology. A fundamental understanding of the complex processes that convert and store energy in living systems is sought. Research supported includes studies that investigate the mechanisms by which energy transduction systems are assembled and maintained, the processes that regulate energy-relevant chemical reactions within the cell, the underlying biochemical and biophysical principles determining the architecture of biopolymers and the plant cell wall, and active site protein chemistry that provides a basis for highly selective and efficient bio-inspired catalysts. Capital equipment is provided for items including advanced atomic force and optical microscopes, lasers and detectors, equipment for x-ray or neutron structure determinations, and Fourier-transform infrared and nuclear magnetic resonance spectrometers.

The research provides basic structure-function information necessary to accomplish solid-phase nanoscale synthesis in a targeted manner; i.e., controlling the basic architecture of energy-transduction and storage systems. This impacts numerous DOE interests, particularly improved biochemical pathways for biofuel production, next generation energy conversion/storage devices, and efficient and environmentally friendly and sustainable catalysts.

In FY 2009, continued emphasis will be placed on probing organizational principles of biological energy transduction and chemical storage systems using advanced molecular imaging and x-ray or neutron methods for structural determination. Research will probe structure-function relationships in biochemical systems and visualize biochemical activity at the molecular level in living cells. In FY 2009, there is an increase for the application of physical characterization tools to biochemical systems ($+1,500,000).

▪ **Catalysis Science**	**39,711**	**39,711**	**56,927**

This activity was formerly named Catalysis and Chemical Transformation. The activity develops the fundamental scientific principles enabling rational catalysts design and chemical transformation control. Research includes the identification of the elementary steps of catalytic reaction mechanisms and their kinetics; construction of catalytic sites at the atomic level; synthesis of ligands, metal clusters, and bio-inspired reaction centers designed to tune molecular-level catalytic activity and selectivity; the study of structure-reactivity relationships of inorganic, organic, hybrid catalytic materials in solution or supported on solids; the dynamics of catalyst structures relevant to catalyst stability; the experimental determination of potential energy landscapes for catalytic reactions; the development of novel spectroscopic techniques and structural probes for *in-situ* characterization of catalytic processes; and the development of theory, modeling, and simulation of catalytic pathways. Capital equipment funding is provided for items such as ultrahigh vacuum equipment with various probes of interfacial structure, spectroscopic analytical instrumentation, specialized cells for *in-situ* synchrotron-based experiments, and computational resources.

Catalytic transformations impact an enormous range of DOE mission areas. Particular emphasis is placed on catalysis relevant to the conversion and use of fossil and renewable energy resources and the creation of advanced chemicals. Catalysts are vital in the conversion of crude petroleum and biomass into clean burning fuels and materials. They control the electrocatalytic conversion of fuels

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

into energy in fuel cells and batteries and play important roles in the photocatalytic conversion of energy into chemicals and materials. Catalysts are crucial to creating new, energy-efficient routes for the production of basic chemical feedstocks and value-added chemicals. Environmental applications of catalytic science include minimizing unwanted products and transforming toxic chemicals into benign ones, such as the transformation of chlorofluorocarbons into environmentally acceptable refrigerants.

In FY 2009, research will focus on the chemistry of inorganic, organic, and hybrid porous materials, the nanoscale self-assembly of these systems, and the integration of functional catalytic properties into nanomaterials. New strategies for design of selective catalysts for fuel production from both fossil and renewable feedstocks will be explored. Increased emphasis will be placed on the use of modern spectroscopy and microscopy to probe both model systems in vacuum and realistic catalytic sites. Research on catalytic cycles involved in electrochemical energy storage and solar photocatalytic fuel formation will receive increased emphasis. In FY 2009, there are increases for ultrafast science ($+1,000,000); chemical imaging of operating catalytic systems ($+750,000); mid-scale instrumentation ($+500,000); solar energy conversion, including photo-catalysis ($+2,838,000); research related to enhanced hydrogen production and use ($+5,128,000), nanoscale catalyst development ($+1,000,000); and experimental and theoretical studies of electrocatalytic processes relevant to electrical energy storage, especially those involving novel electrolytes and ionic liquids ($+6,000,000).

	FY 2007	FY 2008	FY 2009
▪ **Separations and Analysis**	**15,860**	**15,860**	**28,338**

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 new approaches to analysis in complex, heterogeneous environments, including techniques that combine chemical selectivity and spatial resolution to achieve chemical imaging. This activity is the Nation's most significant long-term investment in the fundamental science underpinning actinide separations and mass spectrometry. The overall goal is to obtain a thorough understanding, at molecular and nanoscale dimensions, of the basic chemical and physical principles involved in separations systems and analytical tools so that their full utility can be realized. Capital equipment funding is provided for items such as lasers for use in sample ionization and chemical imaging, advanced mass spectrometers with nanoprobes, confocal microscopes for sub-diffraction limit resolution, and computational resources.

Work is closely coupled to the DOE'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 in, for example, new nuclear fuel systems, and to understand and predict the fate of radioactive contaminants in the environment. Separations are essential to nearly all operations in processing industries and are also necessary for many analytical procedures. An analysis is an essential component of every chemical process from manufacture through safety as well as risk assessment and environmental protection.

In FY 2009, separations research will focus on fluid flow in nanoscale membranes and the formation of macroscopic separation systems via self-assembly of nanoscale building blocks. Chemical analysis research will emphasize the study of hydrogen separation and hydrogen transport within membrane systems; development of techniques with high spatial, temporal, and chemical resolution; and simultaneous application of multiple analytical techniques. In FY 2009, there are increases for advanced chemical separations ($+254,000); analytical chemical imaging ($+1,750,000); mid-scale instrumentation ($+500,000); emergent behavior ($+1,000,000); solar energy conversion ($+1,696,000); research related to the hydrogen economy, including enhanced membrane research ($+2,278,000); and research in membrane and interphase charge transfer and charge transport for electrical energy storage, especially through nanoscale ion channels and their functionalized counterparts ($+5,000,000).

	FY 2007	FY 2008	FY 2009
▪ **Heavy Element Chemistry**	**9,427**	**9,427**	**18,789**

This activity supports research in the chemistry of the heavy elements, including actinides and fission products. The unique molecular bonding of the heavy elements, driven by the active participation of 5f electrons, is explored using theory and experiment to elucidate electronic and molecular structures, bond strengths, and chemical reaction rates. Additional emphasis is placed on the chemical and physical properties of actinides to determine solution, interfacial, and solid-state bonding and reactivity; on determinations of the chemical properties of the heaviest actinide and transactinide elements; and on bonding relationships among the actinides, lanthanides, and transition metals. Capital equipment funding is provided for items such as instruments used to characterize actinide materials (spectrometers, diffractometers, etc.) and equipment to handle the actinides safely in laboratories and at synchrotron light sources.

This activity represents the Nation's only funding for basic research in actinide and fission product chemistry and is broadly relevant to the DOE mission. Knowledge of the chemical characteristics of actinide and fission-product materials under realistic conditions provides a basis for advanced fission fuel cycles. Fundamental understanding of the chemistry of these long-lived radioactive species is required to accurately predict and mitigate their transport and fate in the environments associated with the storage of radioactive wastes.

In FY 2009, funding will support bonding and reactivity studies in solutions, solids, nanoparticles, and interfaces, incorporating theory and modeling, to understand, predict, and control the chemical bonding and reactivity of the heavy elements, especially under extreme conditions of temperature and radiation fields to be found in advanced nuclear energy systems. Increased study of organo-actinide chemistry may provide new insights into metal-carbon bonds with metals that have large ion sizes, f-orbital bonding, and multiple oxidation states. In FY 2009, there are increases for enhanced efforts on actinide chemistry under extreme conditions ($+370,000); mid-scale instrumentation ($+500,000); and enhanced efforts in actinide chemistry and separations science related to advanced nuclear energy systems, especially those aspects related to future reactor or separations design ($+8,492,000).

	FY 2007	FY 2008	FY 2009
▪ **Geosciences Research**	**21,392**	**21,392**	**28,918**

This activity supports basic experimental and theoretical research in geochemistry and geophysics. Geochemical research emphasizes fundamental understanding of geochemical processes and

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

reaction rates, focusing on aqueous solution chemistry, mineral-fluid interactions, and isotopic distributions and migration in natural systems. Geophysical research focuses on new approaches to understand the subsurface physical properties of fluids, rocks, and minerals and develops techniques for determining such properties at a distance; it seeks fundamental understanding of wave propagation physics in complex media and the fluid dynamics of complex fluids through porous and fractured subsurface rock units. Application of x-ray and neutron scattering using BES facilities plays a key role in the geochemical and geophysical studies within this activity. The activity also emphasizes incorporating physical and chemical understanding of geological processes into multiscale computational modeling. Capital equipment funding is provided for items such as x-ray and neutron scattering end stations at the BES facilities for environmental samples and for augmenting experimental, field, and computational capabilities.

This activity provides the basic research in geosciences that underpins the Nation's strategy for understanding and mitigating the terrestrial impacts of energy technologies and thus is relevant to the DOE mission in several ways. It develops the fundamental understanding of geological processes relevant to geological disposal options for byproducts from multiple energy technologies. Knowledge of subsurface geochemical processes is essential to determining the fate and transport properties of harmful elements from possible nuclear or other waste releases. Geophysical imaging methods are needed to measure and monitor subsurface reservoirs for hydrocarbon production or for carbon dioxide storage resulting from large-scale carbon sequestration schemes.

In FY 2009, funding will continue to support research in areas that impact DOE mission areas. Of particular interest are geochemical studies and computational analysis of complex subsurface fluids and solids, including nanophases; understanding the dynamics of fluid flow, particulate transport and associated rock deformation in the deep subsurface; and developing the ability to integrate multiple data types in predictions of subsurface processes and properties. In FY 2009, there are increases for experimental and theoretical geochemical studies of complex subsurface fluids ($+526,000); nanoscale geochemistry ($+1,000,000); mid-scale instrumentation ($+500,000); chemical imaging ($+500,000); and research in solid earth geophysics and geochemistry for understanding the stability and transformations of deep underground carbon sequestration ($+5,000,000).

	FY 2007	FY 2008	FY 2009
▪ **Chemical Energy and Chemical Engineering**	**375**	**—**	**—**

This activity supported research on electrochemistry, thermophysical and thermochemical properties, and physical and chemical rate processes. In FY 2008, remaining chemical energy and chemical engineering research activities were terminated because of competing priorities.

	FY 2007	FY 2008	FY 2009
▪ **General Plant Projects (GPP)**	**9,884**	**9,884**	**705**

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. 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 the Materials Sciences and Engineering subprogram. The total estimated cost of each GPP project will not exceed $5,000,000.

In FY 2009, non-programmatic GPP funding for ORNL and ANL is transferred to the Science Laboratory Infrastructure program to support the SC Infrastructure Modernization Initiative.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
▪ **General Purpose Equipment (GPE)**	**1,214**	**1,214**	**4,243**

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.

Facility Operations	**7,648**	**7,000**	**—**

Beginning in FY 2009, the Combustion Research Facility (CRF) will be budgeted under Chemical Physics Research. The CRF was previously budgeted for as a facility under Facility Operations, but it has been transferred to the research portion of the budget in recognition of its role as a research operation with visitor access via collaboration with staff scientists rather than a user facility.

Facilities

Combustion Research Facility	7,648	7,000	—
SBIR/STTR	**—**	**5,672**	**7,600**

In FY 2007, $5,078,000 and $609,000 were transferred to the SBIR and STTR programs, respectively. The FY 2008 and FY 2009 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

Total, Chemical Sciences, Geosciences, and Energy Biosciences	**217,028**	**222,577**	**297,113**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Atomic, Molecular and Optical Science	
Increases are provided for coherent control of quantum systems ($+1,047,000); ultrafast science ($+2,000,000); chemical imaging ($+500,000); mid-scale instrumentation ($+500,000); and nanoscale science associated with complex systems ($+1,500,000).	+5,547
Chemical Physics Research	
Increases are provided for gas-phase chemical physics focused on combustion of alternative transportation fuels ($+392,000); ultrafast science ($+1,000,000); chemical imaging ($+750,000); mid-scale instrumentation ($+500,000); emergent behavior in condensed phase systems ($+1,000,000); nanoscale interfacial systems ($+1,500,000); solar energy conversion ($+1,697,000); and interfacial chemical physics relevant to electrical energy storage, including studies of electrode-electrolyte interfaces, charge transfer and transport $+3,969,000). Also in FY 2009, includes transfer of the Combustion Research Facility (CRF) from Facility Operations($+7,179,000). The CRF	

	FY 2009 vs. FY 2008 ($000)
was previously budgeted for as a facility under Facility Operations, but it has been transferred to the research portion of the budget in recognition of its role as a research operation with visitor access via collaboration with staff scientists rather than a user facility.	+17,987
Solar Photochemistry	
Increases are provided for ultrafast science ($+1,000,000); solar energy conversion ($+4,686,000); hydrogen ($+1,280,000); and enhanced experimental and theoretical studies of photo-electrochemical and interfacial charge transfer processes in electrical energy storage ($+2,000,000).	+8,966
Photosynthetic Systems	
Increases are provided for chemical imaging ($+750,000); emergent behavior in biological systems ($+500,000); and solar energy conversion ($+3,926,000).	+5,176
Physical Biosciences	
Increase is provided for the application of physical characterization tools to biochemical systems.	+1,500
Catalysis Science	
Increases are provided for ultrafast science ($+1,000,000); chemical imaging of operating catalytic systems ($+750,000); mid-scale instrumentation ($+500,000); solar energy conversion ($+2,838,000); research related to enhanced hydrogen production and use ($+5,128,000); nanoscale catalyst development ($+1,000,000); and experimental and theoretical studies of electrocatalytic processes relevant to electrical energy storage, especially those involving novel electrolytes and ionic liquids ($+6,000,000).	+17,216
Separations and Analysis	
Increases are provided for advanced chemical separations ($+254,000); analytical chemical imaging ($+1,750,000); mid-scale instrumentation ($+500,000); emergent behavior ($+1,000,000); solar energy conversion ($+1,696,000); research related to hydrogen economy ($+2,278,000); and research in membrane and interphase charge transfer and charge transport for electrical energy storage, especially through nanoscale ion channels and their functionalized counterparts ($+5,000,000).	+12,478
Heavy Element Chemistry	
Increases are provided for enhanced efforts in actinide chemistry under extreme conditions ($+370,000); mid-scale instrumentation ($+500,000); and enhanced efforts in actinide chemistry and separations science related to advanced nuclear energy systems, especially those aspects related to future reactor or separations design ($+8,492,000).	+9,362

	FY 2009 vs. FY 2008 ($000)
Geosciences Research	
Increases are provided for research in solid earth geophysics and geochemistry for understanding the stability and transformations of deep underground carbon sequestration ($+5,000,000); experimental and theoretical geochemical studies of complex subsurface fluids ($+526,000); nanoscale geochemistry ($+1,000,000); mid-scale instrumentation ($+500,000); and chemical imaging ($+500,000).	+7,526
General Plant Projects (GPP)	
Decrease in general plant projects due to transfer of non-programmatic GPP funds to the Science Laboratory Infrastructure program to support the SC Infrastructure Modernization Initiative.	-9,179
General Purpose Equipment (GPE)	
Increase for GPE provided for enhanced infrastructure at Ames, ANL, and ORNL.	+3,029
Total, Chemical Sciences, Geosciences and Energy Biosciences Research	**+79,608**
Facility Operations	
Funding for the CRF is transferred from Facility Operations to Research. The CRF was previously budgeted for as a facility under Facility Operations, but it has been transferred to the research portion of the budget in recognition of its role as a research operation with visitor access via collaboration with staff scientists rather than a user facility.	-7,000
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in operating expenses.	+1,928
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences	**+74,536**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Construction			
Advanced Light Source User Support Building, LBNL	1,500	4,954	11,500
Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	—	6,391	3,728
Project Engineering and Design, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	—	941	—
National Synchrotron Light Source-II, BNL	3,000	29,727	93,273
Linac Coherent Light Source, SLAC	101,161	50,889	36,967
Center for Functional Nanomaterials, BNL	18,864	363	—
The Molecular Foundry, LBNL	257	—	—
Center for Integrated Nanotechnologies, SNL/LANL	247	—	—
Total, Construction	125,029	93,265	145,468

Description

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

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

Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet.

The following table shows cost and schedule variance. Note: Cost Variance is the difference between the value of the physical work performed and the actual cost expended. A negative result is unfavorable and indicates the potential for a cost overrun. Schedule variance is the difference between the value of the physical work performed and the value of the work planned. A negative result is unfavorable and indicates that the project is behind schedule. Variance data are shown as percentages. They are shown against the project's performance measurement baseline that includes cost and schedule contingency and are as of the end of each fiscal year. All projects, except those identified in a footnote, have met or are on schedule to meet all Level 0 and Level 1 Milestones, which are shown in the table.

Cost and Schedule Variance

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Estimate
Linac Coherent Light Source, SLAC[a]			
Cost Variance	-5.24%		
Schedule Variance	-15.32%		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	None	None
Linac Coherent Light Source Ultrafast Science Instruments, SLAC			
Cost Variance	Not Baselined		
Schedule Variance	Not Baselined		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 1 – Alternate Selection/Cost Range	None Defined	None Defined
Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC			
Cost Variance	Not Baselined		
Schedule Variance	Not Baselined		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 0 – Approve Mission Need	None Defined	None Defined
Center for Functional Nanomaterials, BNL			
Cost Variance	6.14%		
Schedule Variance	-1.66%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 4a – Start of Initial Operations	Approve Critical Decision 4b – Start of Full Operations	N/A
National Synchrotron Light Source-II, BNL			
Cost Variance	Not Baselined		
Schedule Variance	Not Baselined		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 1 – Alternate Selection/Cost Range	None Defined	None Defined

[a] Due to the delay and reduced funding related to the FY 2007 Continuing Resolution, the project has been directed to prepare a revised cost and schedule baseline. Currently the project has proposed a CD-4 in 4Q FY 2010. The revised cost and schedule is preliminary until approved by the Deputy Secretary. Office of Science IPR and OECM EIR reviews of the revised cost and schedule baseline were conducted in September and October 2007, respectively. The project has submitted a baseline change proposal/request for action and expects approval in 2Q FY 2008.

	FY 2007 Actual	FY 2008 Estimate	FY 2009 Estimate
Instrumentation for Spallation Neutron Source I, ORNL			
Cost Variance	1.33%		
Schedule Variance	-2.26%		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	Approve Critical Decision 4 – Start of Operations for Instruments #1-2	Approve Critical Decision 4 – Start of Operations for Instrument #3
Instrumentation for Spallation Neutron Source II, ORNL			
Cost Variance	Not Baselined		
Schedule Variance	Not Baselined		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 1 – Alternate Selection/Cost Range	None Defined	None Defined
Transmission Electron Aberration Corrected Microscopy (TEAM), LBNL			
Cost Variance	-0.14%		
Schedule Variance	-1.67%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 2 –Performance Baseline Approve Critical Decision 3 – Start of Construction	Approve Critical Decision 4a – Start of Operation TEAM 0.5	Approve Critical Decision 4b – Start of Operation TEAM 1
Advanced Light Source User Support Building, LBNL			
Cost Variance	2.62%		
Schedule Variance	2.98%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 1 – Alternative Selection/Cost Range Approve Critical Decision 2 – Performance Baseline Approve Critical Decision 3 – Start of Construction	None	None

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Advanced Light Source (ALS) User Support Building, LBNL	**1,500**	**4,954**	**11,500**

The ALS User Support Building (USB) will provide high-quality user support space in sufficient quantity to accommodate the significant growth during the past decade in both the number of beamlines and the number of ALS users and to accommodate projected future expansion. The USB will provide staging areas for ALS experiments, including valuable high-bay space, wet laboratories, and temporary office space for visiting users.

FY 2007 PED funding was used to secure a Design-Build contractor to start the preparations of the design documents for the project's critical decisions. In addition, site preparations were completed. FY 2008 funds will be used to complete preparation of the construction solicitation package(s) for USB and perform Title II design services. FY 2009 funds will be used to award construction contract(s) as appropriate and continue the design-build construction projects efforts including Title III construction services. Construction funding for the ALS USB will be completed in FY 2010. This project is using the design-build model for construction, a private-sector best practice for this type of space.

Additional information is provided in the construction project data sheet 08-SC-01.

Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	**—**	**6,391**	**3,728**

Photon Ultrafast Laser Science and Engineering (PULSE) is the new center for ultrafast science at the Stanford Linear Accelerator Center. PULSE represents a major research activity at SLAC that is a key component of the shift in the emphasis of the laboratory from high energy physics to a multiprogram laboratory with significant activities in photon science. The PULSE Center will be located in the Central Laboratory building (B040), a mixed use building of laboratories, offices, meeting rooms, and a library. Approximately 18,000 square feet of existing space in the two-story wing of the Central Laboratory building will be renovated to meet the new PULSE programs needs for offices, laboratories, and conference rooms.

The FY 2008 funding will be used to begin the PULSE Building Renovation. FY 2009 funding is requested to complete construction. Additional information is provided in the construction project data sheet 08-SC-11.

Project Engineering and Design Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	**—**	**941**	**—**

Project Engineering and Design funds for the Photon Ultrafast Laser Science and Engineering Building Renovation, described above, were provided in FY 2008. Additional information is provided in the construction project (08-SC-11) data sheet.

National Synchrotron Light Source-II (NSLS-II), BNL	**3,000**	**29,727**	**93,273**

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

FY 2007 PED funding ($3,000,000) began preliminary design. FY 2008 PED funds will be used to begin final design ($29,727,000). FY 2009 PED funding ($27,273,000) will allow the project to complete final design.

PED funds will assure project feasibility, define the scope, provide 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 ($66,000,000).

Additional information is provided in the construction project data sheet 07-SC-06.

Linac Coherent Light Source, SLAC	**101,161**	**50,889**	**36,967**

The Linac Coherent Light Source (LCLS) Project will provide the world's first demonstration of an x-ray free-electron-laser (FEL) in the 1.5–15 Ångstrom range. The 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 FY 2007 funding continued Project Engineering and Design (PED) Title I and Title II design work and 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 renovation of existing buildings at SLAC to provide office space requirements to support LCLS operations. In addition, the assembly and delivery of the undulators and undulator infrastructure to SLAC's Magnetic Measurement Facility was completed. Delivery of the undulators in FY 2007 enables achievement of performance goals in FY 2009.

Construction funding in FY 2008 will be used to complete most of the LCLS conventional facilities and for continued procurement and installation of the technical hardware.

The project was impacted by the delay and reduction in FY 2007 funding the procurement for the x-ray optics, diagnostics, and end stations. The project has revised the cost and schedule, and the revised baseline was evaluated in late 2007. The revised project baseline was submitted to the Deputy Secretary for approval in 1Q FY 2008. FY 2009 funding is requested to continue technical equipment procurements and installation. Commissioning of the facility will also continue on a phased schedule.

Additional information on the LCLS project is provided in the LCLS construction data sheet, project number 05-R-320.

Center for Functional Nanomaterials, BNL	**18,864**	**363**	**—**

The Center for Functional Nanomaterials (CFN), a BES Nanoscale Science Research Center, will be completed on time and within budget in FY 2008.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
The Molecular Foundry, LBNL	**257**	**—**	**—**

The Molecular Foundry, a BES Nanoscale Science Research Center, was completed on time and within budget in FY 2007.

Center for Integrated Nanotechnologies, SNL/LANL	**247**	**—**	**—**

The Center for Integrated Nanotechnologies (CINT), a BES Nanoscale Science Research Center, was completed on time and within budget in FY 2007.

Total, Construction	**125,029**	**93,265**	**145,468**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Advanced Light Source (ALS) User Support Building, LBNL	
Increase in funding for construction of the ALS User Support Building, as scheduled.	+6,546
Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	
Decrease in funding representing the completion of construction in FY 2009, as scheduled.	-2,663
Project Engineering and Design, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	
Decrease due to completion of PED in FY 2008.	-941
National Synchrotron Light Source-II (NSLS II), BNL	
Decrease in funding to continue Project Engineering and Design ($-2,454,000) and increase to initiate construction ($+66,000,000), as scheduled.	+63,546
Linac Coherent Light Source, SLAC	
Decrease in funding to continue construction of the LCLS project, representing the scheduled ramp down of activities.	-13,922
Center for Functional Nanomaterials, BNL	
Decrease in funding for construction of the Center for Functional Nanomaterials at BNL, representing completion of construction funding.	-363
Total Funding Change, Construction	**+52,203**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
General Plant Projects	16,336	10,006	2,152
Accelerator Improvement Projects	16,294	15,411	32,643
Capital Equipment	74,795	74,382	154,317
Total, Capital Operating Expenses	107,425	99,799	189,112

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Unappro-priated Balances
08-SC-01 Advanced Light Source User Support Building, LBNL	35,700[a]	—	—	4,954	11,500	17,746
08-SC-10 PED, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	941	—	—	941	—	—
08-SC-11 Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC	11,060[b]	—	—	6,391	3,728	—
07-SC-06, National Synchrotron Light Source-II, BNL	791,200	—	3,000	29,727	93,273	665,200
07-SC-12, PED, Advanced Light Source User Support Building, LBNL	1,500	—	1,500	—	—	—
05-R-320 Linac Coherent Light Source, SLAC	352,000[c]	111,930	101,000	50,889	36,967	15,240
05-R-321 Center for Functional Nanomaterials, BNL	79,697[d]	54,505	18,864	363	—	—
04-R-313 The Molecular Foundry, LBNL	83,604[e]	76,132	257	—	—	
03-SC-002, PED, Linac Coherent Light Source, SLAC	35,974	35,813	161	—	—	—

[a] Includes $1,500,000 of PED included in the 07-SC-12 PED, LBNL Advanced Light Source User Support Building datasheet.
[b] Includes $941,000 of PED included in the 08-SC-10 PED, Photon Ultrafast Laser Science and Engineering Building Renovation, SLAC datasheet.
[c] Includes 35,974,000 of PED included in the 03-SC-002 PED, SLAC, Linac Coherent Light Source datasheet.
[d] Includes $5,966,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[e] Includes $7,215,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Unappro-priated Balances
03-R-313 Center for Integrated Nanotechnologies, SNL/LANL	73,754[a]	69,348	247	—	—	—
Total, Construction			125,029	93,265	145,468	

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

(dollars in thousands)

	Total Project Cost (TPC)	Other Project Costs (OPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Completion Date
Spallation Neutron Source Instrumentation I (31MK), ORNL[b]	68,500		68,500	28,744	10,500	11,856	12,000	FY 2011
Transmission Electron Aberration Corrected Microscope (61PC), LBNL	27,087	15,487	11,600	2,000	3,500	6,100	—	FY 2009
Spallation Neutron Source Instrumentation II (71RB), ORNL[c]	40,000–60,000		40,000–60,000	—	500	6,000	7,000	TBD
Linac Coherent Light Source Instrumentation (71RA), SLAC[d]	50,000–60,000		50,000–60,000	—	500	6,000	15,000	TBD
Total, Major Items of Equipment				30,744	15,000	29,956	34,000	

[a] Includes $4,159,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[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.
[c] Mission Need (CD-0) was approved on October 31, 2005 with a TPC range of $40–60M. The baseline TPC will be approved at CD-2 (Approve Performance Baseline).
[d] Mission Need (CD-0) was approved on August 10, 2005 with a TPC range of $50–60M. The baseline TPC will be approved at CD-2 (Approve Performance Baseline).

Advanced Scientific Computing Research

Funding Profile by Subprogram

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY2 008 Current Appropriation	FY 2009 Request
Advanced Scientific Computing Research					
Mathematical, Computational, and Computer Sciences Research	107,117	133,652	—	133,652	151,304
High Performance Computing and Network Facilities	168,617	220,746	-3,225[a]	217,521	217,516
Total, Advanced Scientific Computing Research	275,734[b]	354,398	-3,225[a]	351,173	368,820

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 108-423, "Department of Energy High-End Computing Revitalization Act of 2004"
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007"

Mission

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

Strategic and GPRA Unit Program Goals

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

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

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

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

[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.
[b] Total is reduced by $7,681,000: $6,858,000 of which was transferred to the SBIR program and $823,000 of which was transferred to the STTR program.

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

Contribution to GPRA Unit Program Goal 3.1/2.51.00, Deliver forefront computational and networking capabilities

The ASCR program contributes to this goal 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 both facilities and colleagues to enable scientific discovery.

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

The following indicators establish specific long term (ten year) goals in Scientific Advancement that the ASCR program is committed to, and progress can be measured against. The Advanced Scientific Computing Advisory Committee (ASCAC) was charged to review progress toward these long term measures and reported "good to excellent" progress to the Department in November, 2006. The long term measures are:

- Develop multiscale mathematics, numerical algorithms, and software that enable more effective models of systems such as the earth's climate, the behavior of materials, or the behavior of living cells that involve the interaction of complex processes taking place on vastly different time and/or length scales; and
- Develop, through the Genomics: GTL partnership with the Biological and Environmental Research (BER) program, the computational science capability to model a complete microbe and a simple microbial community. This capability will provide the science base to enable the development of novel clean-up technologies, bio-energy sources, and technologies for carbon sequestration.

Funding by Strategic and GPRA Unit Program Goal

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.51.00, Deliver Forefront Computational and Networking Capabilities			
Advanced Scientific Computing Research	275,734	351,173	368,820

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 3.1/2.51.00 (Deliver Forefront Computational and Networking Capabilities)					
Mathematical, Computational, and Computer Sciences Research					
Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. [Goal Met]	Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. [Goal Met]	Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2006—>50%. [Goal Met]	Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2007—>100% [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. FY 2008—>100%	Improve Computational Science Capabilities. Average annual percentage increase in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes. FY 2009—>100%
High Performance Computing and Network Facilities					
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]				
Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used was accounted for by computations that required at least 1/8 of the total resource. [Goal Not Met]	Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that was accounted for by computations that require at least 1/8 of the total resource. [Goal Met]	Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that was accounted for by computations that require at least 1/8 of the total resource. FY 2006—40%. [Goal Met]	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 (760 processors) of the total resource. FY 2007—40% [Goal Met]	Focus usage of the primary supercomputer at the National Energy Research Scientific Computing Center (NERSC) on capability computing. Thirty percent (30%) of the computing time will be used by computations that require at least 1/8 (2,040 processors) of the NERSC resource. FY 2008 goal 30%.	Focus usage of the primary supercomputer at the National Energy Research Scientific Computing Center (NERSC) on capability computing. Thirty percent (30%) of the computing time will be used by computations that require at least 1/8 (2,040 processors) of the NERSC resource. FY 2009 goal 30%.

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 supports the following means:

- Ensure competitively selected, peer and merit reviewed basic research in relevant areas of mathematics, computer science, computational science, and network technology necessary to achieve program and Department goals.
- Deliver computing facilities and advanced networks necessary to advance research in the relevant areas of science and technology necessary to achieve program and Department goals.
- Ensure effective management processes for timely and cost effective investments resulting in desired deliverables.
- Utilize input from the scientific community to ensure progress is made and opportunities identified.
- Form mutually beneficial partnerships with programs sharing common goals.

ASCR utilizes the following strategies:

- Utilize external review to inform joint planning—In 2006, both the ASCR and Biological and Environmental Research (BER) advisory committees have been charged with reviewing progress toward the programs common goal for computational biology. Both committees recognized that excellent research was being supported toward this goal. However, the Advanced Scientific Computing Advisory Committee (ASCAC) expressed concern about progress toward the computational models described in the goal. A joint panel has been formed to recommend specific strategies for accelerating progress in model development and the programs will jointly implement the recommendations. This panel's work will be greatly informed by several related reports of the National Academies of Science that were sponsored by the two programs.
- Utilize external review to prioritize program investments—In 2006, the ASCAC found excellent research was being supported toward the ASCR goal in Applied Mathematics and that excellent progress was being made toward this goal. However, the committee believes that opportunities in multiscale mathematics greatly outweigh resources and that increased investment in this area would have broad impacts on Department goals. ASCR has requested increases for this area of research in both FY 2008 and FY 2009.

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.

Validation and Verification

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

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. ASCR has incorporated feedback from OMB into the FY 2009 budget request and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB assigned 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. In addition, OMB found that the program supports world-class scientific user facilities, has demonstrated an improved level of interagency communication and cooperation, was then drafting a long-term strategic vision, and has been very successful with a major effort in interdisciplinary software. However, OMB was concerned that the program's external advisory committee, ASCAC, was underutilized. The assessment found that ASCR has developed a limited number of adequate performance measures which are continued for FY 2009 with a rewording of the NERSC measures to enhance the transparency of our progress in high performance capacity computing. 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. Roadmaps, developed in consultation with ASCAC, will guide reviews every three years by ASCAC of progress toward achieving the long-term performance goals of the program. In April 2006, ASCAC was charged to conduct the first such review of progress toward the long-term measures. ASCAC reported to the Department on November 10, 2006, with ratings of good and excellent. The committee reports are available at http://www.sc.doe.gov/ascr/ascac_reports.htm. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report which is available at http://www.cfo.doe.gov/progliaison/part2005.htm.

For FY 2007, there were four new PART related actions and two continuing actions for ASCR.

- Engage advisory panel in an assessment of the strategic priorities for the program, focusing on the balance between "core" research and supercomputing hardware investments. (FY 2007)
- Engage 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. (FY 2006)
- Implement action plans for improving program management in response to past expert reviews. (FY 2005)
- Develop new annual measures to track how efficiently the program's supercomputers are operated and maintained on a unit per dollar basis by July, 2007. (FY 2007)
- Improve the quality of the supporting materials for the Office of Science IT Exhibit 300 business cases submitted to OMB, especially the alternative analysis, acquisition strategy, and risk management sections. (FY 2007)

- Participate in the development of a unified, action-based strategy for SC-wide collaboration in accelerator and detector R&D (including advanced accelerator concepts) by March 1, 2007. (FY 2007)

In response to these OMB recommendations ASCR has:

- Charged the ASCAC to assess the strategic priorities of the program focusing on the balance between the "core" research and facilities. Their report is expected in February 2008.
- Established a Committee of Visitors (COV) to provide outside expert validation of the program's merit-based review processes for impact on quality, relevance, and performance. ASCR made changes in procedures and program manager training to respond to the recommendations of the first two COVs, which focused on the research programs and facilities, respectively. ASCR continues to host COVs and other panels to review the quality, relevance, and performance of the program. The most recent COV focused on the SciDAC program in July 2007. The report and program action plan is posted on both the PART website and at: http://www.sc.doe.gov/ascr/ASCAC/Reports.html
- Developed, in response to the recommendations of past expert reviews, a program manager manual and training course to improve the consistency and quality of program documentation. A "Management Model for Delivering High Performance and Leadership Class Computing Systems for Scientific Discovery"; and a new "Management Model for ESnet" were also developed.
- Revised the National Energy Research Scientific Computing Center (NERSC) facility measure to clarify progress in capacity computing. Experience has shown facility management efficiencies are best realized via a regular and detailed examination of operational procedures, so ASCR will require annual Facility Operations Review by a panel of independent external experts. The reviews will evaluate the performance and cost of operations of the facility; assess the level of resources needed to effectively support the facility's mission and identify opportunities to optimize efficiency and performance of the facility.
- Performed annual program operations reviews of the ASCR facilities: NERSC and the Leadership Computing Facilities at both Oak Ridge National Laboratory (OLCF) and Argonne National Laboratory (ALCF). Operational assessments were conducted for NERSC and the LCFs in August, 2006 and May, 2007. As a guideline for these reviews, in FY 2007, ASCR developed a "Management Model for Delivering High Performance and Leadership Class Computing Systems for Scientific Discovery" and a corresponding "Operational Assessment Program Plan." The reviews and plans will directly contribute to improving management of the facilities and will improve the quality and consistency of project documentation.
- Submitted a unified, action-based strategy for SC-wide collaboration in accelerator and detector R&D to OMB on February 26, 2007. A working group has been formed with regular meetings and updates. ASCR contributions in this area of research are focused on simulation and modeling efforts and include the FY 2007 SciDAC project entitled Community Petascale Project for Accelerator Science and Simulation (COMPASS) which is linked to seven other SciDAC Institutes and Centers.

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

Basic and Applied R&D Coordination

Applied Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment: The ASCR program is requesting $2,000,000 to support basic research in advanced mathematics for optimization of complex systems, control theory, and risk assessment. This R&D integration focus area was the subject of an ASCR workshop held in December 2006. The workshop recommended additional research emphasis in advanced mathematics could benefit the optimization of fossil fuel power generation, the nuclear fuel lifecycle, and power grid control. Such research could increase the likelihood for success in DOE strategic initiatives including FutureGen and the modernization of the power grid.

Applied technology offices within DOE that could benefit from this research integration effort include: the Offices of Electricity Delivery and Energy Reliability (for their research on electric power grid control and optimization); Nuclear Energy (for development of advanced design and simulation codes); Energy Efficiency and Renewable Energy (for development of first principles models with applications to biofuels, hydrogen storage, and vehicle technologies); and Fossil Energy (for FutureGen and advanced generation engineering).

Carbon Dioxide Capture and Storage: The ASCR program is requesting $976,000 to continue two projects, selected in the FY 2006 re-competition of the SciDAC portfolio and jointly funded by ASCR and BER. These projects are: a five-year “Modeling Multiscale-Multiphase-Multicomponent Subsurface Reactive Flows using Advanced Computing” project and a three-year “Hybrid Numerical Methods for Multiscale Simulations of Biochemical Processes” project. They were selected to advance modeling of subsurface reactive transport of contaminants across multiple length scales and have also been identified as directly relevant to carbon sequestration research efforts.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Applied Mathematics for Optimization of Complex Systems, Control Theory, and Risk Assessment			
Mathematical, Computational, and Computer Sciences Research	—	1,900	2,000
Carbon Dioxide Capture and Storage			
Mathematical, Computational, and Computer Sciences Research	—	976	976
Total, Basic and Applied R&D Coordination	—	2,876	2,976

Overview

Computational modeling and simulation has become a third pillar, along with experiment and theory, of scientific inquiry. Scientific computing is particularly important for the solution of research problems that are unsolvable through traditional theoretical and experimental approaches, or are too hazardous, 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’s research projects in applied mathematics, computer science, and networking provide key tools and techniques to help the other SC programs achieve their research objectives. The applied mathematics research program develops and implements the fundamental methods to allow scientists to effectively utilize high performance computers to accurately model complex physical, chemical, and biological processes and systems. ASCR’s computer science research efforts help scientists make the most efficient use of high-performance computing systems as they simulate, analyze, visualize, manage, and store massive amounts of data, gaining new insight from complex scientific modeling applications and on-line experimental facilities around the world. Networking research sponsored by ASCR enables scientists at research labs and universities to collaborate, access and share data, and effectively manage high-demand scientific resources.

ASCR's other main responsibility is to provide the DOE research community with the high-performance computing and networking tools required to support world-class scientific leadership. Dramatic advances in computational science—made possible, in part, by ASCR research programs and computing systems—underscore the importance of strengthening computational science as the Nation strives to maintain its global competitiveness in science, education, and commerce. The Administration has recognized the importance of high-end computing to the Nation. The President identified supercomputing as an important component of his American Competitiveness Initiative in the 2006 State of the Union Address. The High End Computing Revitalization Task Force (HECRTF) report was published in May 2004 and ASCR continues to implement that plan through this budget request.

The National Academies are conducting a study, which was described in the President's FY 2006 Budget Request, entitled "Toward Better Understanding the Potential Impact of High-End Capability Computing on Science and Technology" to "enable a better understanding of the potential scientific impact of high-end capability computing that identifies and categorizes important scientific questions and technology problems for which an extraordinary advancement in our understanding is difficult or impossible without leading edge scientific simulation capabilities." This study is expected to better inform decision makers about the potential impact of computational science in general and ASCR's approach in particular.

As we look to the next generation of computers, we anticipate hardware that is significantly more complex and difficult to use than current systems. These machines will contain significantly more (100–1,000 times more) possessors that will contain more processing units (for example, the Intel teraflop research chip implements 80 simple cores, each containing two programmable floating point engines). These processors will also likely move from horizontal two-dimensional designs to innovative three-dimensional chip stacking (for example, IBM's "*through-silicon via*" process to create 3-D integrated stacked chips). These changes will require multiple levels of memory hierarchy and interconnects which introduce other significant challenges. As a consequence, many of the tools, software, algorithms, and libraries that we have developed for today's computers will have to be revised or replaced to effectively operate at extreme scales. As was the case with terascale computing, success will be built on a decade of research effort focused on the challenges of hardware not yet available. Therefore, it is important for ASCR to carefully balance investments in facilities and research. To make this balance more transparent, ASCR has split the Mathematical, Information, and Computational Science (MICS) subprogram into two subprograms: Mathematical, Computational, and Computer Sciences Research and High Performance Computing and Network Facilities.

Advisory and Consultative Activities

The ASCAC provides valuable independent advice to DOE on a variety of complex scientific and technical issues related to the ASCR program. The ASCAC is charged with providing advice on promising future directions for advanced scientific computing research, strategies to couple advanced scientific computing research to other disciplines, and the relationship of the DOE program to other Federal research investments. ASCAC's recommendations include advice on long-range plans, priorities, and strategies to address more effectively the scientific aspects of advanced scientific computing including the relationship of advanced scientific computing to other scientific disciplines, and maintaining appropriate balance among elements of the program. This advisory committee plays a key role in assessing the scientific and programmatic merit of presently funded activities and in evaluating plans for the future. The Committee formally reports to the SC Director and includes representatives from universities, national laboratories, and industries who are involved in advanced computing research. Particular attention is paid to obtaining a diverse membership with a balance among scientific disciplines, institutions, and geographic regions. ASCAC operates in accordance with the Federal Advisory Committee Act (FACA), Public Law 92–463; and all applicable FACA Amendments, Federal Regulations, and Executive Orders.

The activities funded by the ASCR program are coordinated with other Federal efforts through the NITRD subcommittee of the NSTC. The Federal Information Technology (IT) R&D agencies have established over a decade of highly successful collaborative accomplishments in multiagency projects and in partnerships with industry and academic researchers. The multiagency approach leverages the expertise and perspectives of scientists and technology users from many agencies who are working on a broad range of IT research questions across the spectrum of human uses of information technology. DOE has been an active participant in these coordination groups and committees since their inception and the ASCR program will continue to coordinate its activities through these mechanisms including an active role in implementing the Federal IT R&D FY 2002–2006 Strategic Plan under the auspices of the NSTC and OSTP.

The ASCR program must coordinate and prioritize a large number of goals from agency and interagency strategic plans; requests from other SC programs and the National Nuclear Security Administration (NNSA); demand for network and computing capacity and capability; and community identified research opportunities (from individual proposals to reports from workshops and the National Academies of Science); while also balancing immediate and long-term needs.

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 flexible to respond to developments in a fast paced area of research. In FY 2007, ASCAC was charged with assessing the priorities and balance of the ASCR portfolio. Their report is expected February 2008.

Also in FY 2007, a series of town hall meetings were held to gather community input to identify scientific opportunities that required more advanced computing capability than currently available. These meetings were very well attended, reflecting great excitement in the research community. The reports document the potential for significant contributions to the DOE missions in Energy, Ecology, and Security but they also document significant challenges to the effective utilization of the more powerful and complex machines currently envisioned.

The key planning elements for this program are:

- The Department and SC Strategic Plan, as updated through program collaborations and joint advisory committee meetings (www.sc.doe.gov/Sub/Mission/mission_strategic.htm);
- The HECRTF Plan (www.nitrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf) (May 2004);
- The Federal Plan for Cyber Security and Information Assurance Research and Development (www.itrd.gov/pubs/csia/csia_federal_plan.pdf) (April 2006);
- The (Interim) Federal Plan for Advanced Networking Research and Development (May 2007);
- Intra- and inter-agency working groups, committees, and workshops; and
- Reports from ASCR sponsored workshops and town hall meetings.

Mathematical, Computational, and Computer Sciences Research

Funding Schedule by Activity

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Mathematical, Computational, and Computer Sciences Research			
Applied Mathematics	28,804	36,900	43,164
Computer Science	23,020	29,000	34,618
Computational Partnerships	41,695	50,246	52,064
Next Generation Networking for Science	13,598	13,764	17,221
SBIR/STTR	—	3,742	4,237
Total, Mathematical, Computational, and Computer Sciences Research	107,117	133,652	151,304

Description

The Mathematical, Computational, and Computer Sciences Research (Research) subprogram is responsible for carrying out the research elements of the ASCR program: To enable scientists nationwide to effectively utilize forefront computational and networking capabilities to extend the frontiers of science, addressing a range of science issues that include the function of living cells and the power of fusion energy. Computational science is increasingly central to progress at the frontiers of almost every scientific discipline and to our most challenging feats of engineering. Accordingly, we must address the following questions:

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

FY 2007 Accomplishments

- *SciDAC Team Develops First Principles Simulations of Sawtooth Oscillations in Tokamaks.* Sawtooth oscillations are periodic events occurring near the center of tokamak plasmas under certain conditions and can have a significant impact upon the performance of burning plasmas. Researchers at the SciDAC Center for Extended Magnetohydrodynamic Modeling (CEMM) have performed self-consistent simulations of repetitive sawtooth cycles for the CDX-U tokamak using the two extended nonlinear MHD codes of the Center—NIMROD and M3D—obtaining excellent agreement between the two codes and good agreement with the experiment.

- *Employing SciDAC visualization tools to advance Fusion Energy science.* The SciDAC Institute for Ultrascale Visualization has developed a data exploration system that visualizes time-varying, multivariate point-based data from gyrokinetic particle simulations allows discovery of interesting features within the data. Another SciDAC team, the Visualization and Analytics Center for Enabling Technologies (VACET), is also working with PPPL to deploy tools for query based visualization of particle fusion data. The deployment of these tools allows fusion scientists to more fully explore their data as part of their verification and validation process which is a critical component in the development of simulation codes.
- *Multiscale Mathematics delivers more realistic models of Hanford contamination.* Research at PNNL and Brown University built a three dimensional (3-D) statistical conceptual model for Hanford site and conducted first of a kind 3-D stochastic flow simulations for the entire site. Previously, stochastic simulations were limited to the small domains within Hanford site. The PNNL team improved the underlying mathematics which allowed the researchers to build a more-realistic 3-D simulation of the Hanford site. This will inform field research and monitoring activities to improve remediation efforts.
- *Improving the mathematics of earthquake simulations*. A team of researchers at Lawrence Livermore National Laboratory have implemented the 3-D elastic wave equation in a code called “WPP”. It uses the Message Passing Interface (MPI) library for parallel computations on a Cartesian grid, with variable wave speeds and density throughout the domain with a free-surface boundary condition. They also implemented general point-force and moment-source terms to model the 1906 San Francisco Earthquake for the 100 year anniversary. This simulation covered a 550 km by 200 km by 40 km domain of northern California on a 125 meter grid, leading to roughly 2.2 Billion grid points and required about 24 hours of CPU time to simulate the first 300 seconds of the earthquake. The team has also applied their methods to problems in underwater acoustics and nondestructive evaluation. Many of these results have been implemented in the massively parallel, seismic simulation software, WPP, the first version of which was recently released as open source.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Applied Mathematics	**28,804**	**36,900**	**43,164**

This activity supports the research, development, and application of applied mathematical approaches (algorithms) for translating physical, chemical, and biological processes into numerical libraries and tools that enable scientific computing applications to calculate and solve larger and more complex problems that may otherwise be unsolvable. This activity supports research at DOE laboratories, universities, and private companies, including partnerships between DOE’s national laboratories and universities.

The Applied Mathematics activity supports research on vital areas important to creating and improving algorithms, including:

- Numerical methods for solving ordinary and partial differential equations, especially numerical methods for computational fluid dynamics. PDEs describe problems involving unknown relationships between several variables, enabling simulations of things like fluid flow, wave propagation, and other phenomena.
- Computational meshes for complex geometrical configurations, which seek to translate domains of mathematical values into discrete points to simulate continuous processes like combustion.
- Numerical methods for solving large systems of linear and nonlinear equations.
- Optimization, which seeks to minimize or maximize mathematical functions and can be used to find the most efficient solutions to engineering problems or to discover physical properties and biological configurations. This includes optimization, control, and risk assessment in complex systems with relevance for DOE missions in Energy, National Security, and Environment.
- Multiscale computing, which connects varying scales in the same problem, such as relating processes and properties at the tiniest scales of time and space to those at the largest scales.
- Multiphysics computations, which simulate physical processes of different kinds, such as a chemical reaction at its boundary with a material.
- Math software and libraries—modular codes that can be incorporated into programs from diverse science areas, allowing developers to quickly build software that performs difficult calculations efficiently and rapidly.

New for FY 2009 will be a joint Applied Mathematics-Computer Science Institute to focus on the challenges of computing at extreme scales that blur the boundaries between these disciplines. In addition, a new effort in the mathematics of large datasets will be initiated in FY 2009 to address the most fundamental issues in finding the dots (key features), connecting the dots (relationships between the key features), and understanding the dots (extracting scientific insights) in extremely large datasets.

Early Career Principal Investigator awards given to exceptionally talented university investigators in Applied Mathematics will continue to be supported. The Computational Science Graduate Fellowship Program, aimed at attracting the best graduate students in the scientific disciplines and helps educate them as the next generation of computational scientists, is continued at $6,000,000.

	FY 2007	FY 2008	FY 2009
Computer Science	**23,020**	**29,000**	**34,618**

This activity supports research in computer science to enable computational scientists to effectively utilize computing at extreme scales to advance science in areas important to the DOE mission. DOE has unique requirements for high performance computing that significantly exceed the capability of software products from computer vendors.

The Computer Science activity supports research in two general areas: the underlying software to enable applications to make effective use of computers at extreme scales—many thousands of multi-core processors with complicated interconnections; and large-scale data management and visualization for both local and remote data analysis. Researchers at DOE laboratories and universities, often working in partnerships, propose and conduct this research in:

- Scalable software tools to diagnose and monitor the performance of software and scientific application codes to enable users to improve performance and get scientific results faster;
- new programming models that scale to hundreds of thousands of processors to simplify application code development for petascale computing;
- advanced techniques for visualizing and managing very large-scale scientific data; and
- efforts to improve application performance through innovative next generation operating systems.

Effective understanding and utilization for science, of computing at extreme scales will require dynamic behavior of system software (operating systems, file systems, compilers, performance tools) than historically developed due to the rapid introduction of these highly complex machines. Substantial innovation is needed to provide essential system software functionality in a timeframe consistent with the anticipated availability of hardware.

In FY 2009, the Computer Science activity will continue to support the most promising long-term efforts in software and data management, analysis and representation for computing at extreme scales. Early Career Principal Investigator awards to exceptionally talented university investigators in Computer Science, who are at an early stage in their professional careers, will continue to be supported. Computer Science will continue to support the Institute for Advanced Architectures and Algorithms with Centers of Excellence at Sandia National Laboratories and Oak Ridge National Laboratory, established in FY 2008.

New for FY 2009 will be direct support for science application "leading edge developers" willing to take on the risks of working with new and emerging languages and tools. Also new for FY 2009 will be a joint Applied Mathematics-Computer Science Institute to focus on the challenges of computing at extreme scales that blur the boundaries between these disciplines.

	FY 2007	FY 2008	FY 2009
Computational Partnerships	**41,695**	**50,246**	**52,064**

This activity supports Scientific Discovery through Advanced Computing (SciDAC). 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 the reactive transport of contaminants through groundwater). 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 through simulation and modeling.

In FY 2009, this activity will support the SciDAC Science Applications and Partnerships, Centers for Enabling Technologies (CET), and SciDAC Institutes that were competitively selected in FY 2006. Some of the three year Science Application partnerships will be completed in FY 2008, resulting in a slight decrease in this program for FY 2009.

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

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

The Scientific Applications Partnerships (SAPs) support collaborative research of applied mathematicians and computer scientists with domain scientists to develop and apply computational techniques and tools to address the specific problems of a particular Science Application team. This effort tests the usefulness of advances in computational research, transfers the results of this research to the scientific disciplines and helps define opportunities for future research.

With 70 participating institutions and hundreds of researchers developing tools, techniques and software that push the state-of-the-art in high performance computing, ASCR needed to ensure that the SciDAC teams shared information across projects and, to leverage taxpayer investment, with others in industry, government and academia. A SciDAC Outreach Center was established as a pilot in FY 2007 at Lawrence Berkeley National Laboratory. The goal is to provide a single resource, knowledgeable with regard to the expertise and resources included in the SciDAC portfolio, to facilitate and accelerate the transfer of tools, techniques, and expertise to the broader research community. The SciDAC Outreach Center has become a resource for Innovative and Novel Computational Impact on Theory and Experiment (INCITE) applicants who need assistance in readying their application to effectively utilize leadership resources. This pilot will be peer reviewed in FY 2008 to evaluate the effectiveness of this approach in broadening the impact of SciDAC.

In the competitively selected FY 2006 SciDAC awards, partnerships have been formed with SC programs in Basic Energy Sciences (BES), Biological and Environmental Research (BER), Fusion Energy Sciences (FES), High Energy Physics (HEP), and Nuclear Physics (NP), and with the National Nuclear Security Administration (NNSA). These Science Application projects are coupled to the SciDAC CETs and Institutes and may include a dedicated SAP. Areas under investigation include nuclear physics (HEP, NP, and NNSA); petascale data (HEP); accelerator physics and design (HEP, NP, and BES); computational astrophysics (HEP, NP, and NNSA); quantum chromodynamics (HEP and NP); computational biology, ground water modeling and simulation, and climate models (BER); plasma

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

turbulence in tokamaks (FES); Accelerator R&D (HEP, NP, and BES); chemistry (BES); and turbulence and materials science (NNSA). This activity also supports continuing partnerships with BES in nanoscience; with BER in Genomics: GTL, and with FES on the Fusion Simulation Project (FSP).

In FY 2009, the partnership with BER in climate models will be expanded to improve the representation of ice sheets in global circulation—a critical source of uncertainty in current Earth-systems models.

Next Generation Networking for Science	**13,598**	**13,764**	**17,221**

This activity, previously Distributed Network Environment, builds on the fundamental results of computer science to develop integrated software tools and advanced network services to enable large-scale scientific collaboration and make effective use of distributed computing and science facilities to advance the DOE science mission.

The Next Generation Networking for Science activity primarily supports research and development in three areas to enable SC to exploit new capabilities being made available by ESnet and other national research and education networks to provide scientific data where it is needed at speeds commensurate with the new data volumes:

- distributed systems software, tools, and services to enable the discovery, management, and distribution of extremely large data sets generated by simulations or by science experiments such the Large Hadron Collider (LHC) in HEP and ITER in FES,
- advanced network protocols, optical network services, tools, and protocols to interconnect and provide access to LCFs and science facilities; and
- high-performance middleware to facilitate secure national and international scientific collaborations.

In FY 2007, an interagency working group, led by ASCR, the Department of Defense and the National Science Foundation, developed a draft plan for Advanced Networking Research and Development to identify key research areas necessary to deliver future networking technologies that are critical for science but also for U.S. economic and national security. This interagency plan will provide a framework in which ASCR research can address key issues for science and leverage effectively on research sponsored by other agencies. The Next Generation Networking for Science activity will begin to implement key elements of that plan most relevant for open science networks in FY 2008.

For FY 2009, the Next Generation Networking for Science activity will initiate a basic research effort in cyber security focused on the unique needs of open science networks and computing facilities. This activity will be informed by the Federal Plan for Cyber Security and Information Assurance Research and Development and by two ASCR workshops on research needs for cyber security in open science held in FY 2007.

Early Career Principal Investigator awards given to exceptionally talented university investigators in Networking will continue to be supported.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR)	**—**	**3,742**	**4,237**

In FY 2007, $2,594,000 and $311,000 were transferred to the SBIR and STTR programs respectively. The FY 2008 and FY 2009 amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs.

Total, Mathematical, Computational, and Computer Sciences Research	**107,117**	**133,652**	**151,304**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Applied Mathematics	
This increase will support a new joint Applied Mathematics-Computer Science Institute to focus on the challenges of computing at extreme scales that blur the boundaries between these disciplines, a new effort in the mathematics of large datasets to address the most fundamental issues in finding the key features, understanding the relationships between those features, and extracting scientific insights in extremely large datasets, and increases in key areas of long-term research most relevant to meeting the challenges of computing at extreme scale and risk assessment in complex systems.	+6,264
Computer Science	
This increase will support a new joint Applied Mathematics-Computer Science Institute, a new effort to provide direct support for science application “leading edge developers” willing to take on the risks of working with new and emerging languages and tools, and increases in key areas of long-term research most relevant to meeting the challenges of computing at extreme scale and risk assessment in complex systems.	+5,618
Computational Partnerships	
Funding is reduced for Science Application Partnerships selected in FY 2006 which will be completed in FY 2008 (-$1,182,000). The partnership with BER in climate models will be expanded to improve the representation of ice sheets in global circulation—a critical source of uncertainty in current Earth-systems models (+$3,000,000).	+1,818
Next Generation Networking for Science	
This increase will support a new basic research effort in Cyber Security for Open Science. Investment would be informed by ASCR workshops and elements of the Federal Plan for Cyber Security and Information Assurance Research and Development most relevant to open science.	+3,457

	FY 2009 vs. FY 2008 ($000)
SBIR/STTR	
Increase in SBIR/STTR due to increase in operating expenses.	+495
Total Funding Change, Mathematical, Computational, and Computer Sciences Research	**+17,652**

High Performance Computing and Network Facilities

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
High Performance Computing and Network Facilities			
High Performance Production Computing	37,554	54,200	54,790
Leadership Computing Facilities	94,910	110,158	115,000
Research and Evaluation Prototypes	14,313	23,100	17,000
High Performance Network Facilities and Testbeds	21,840	24,336	25,000
SBIR/STTR	—	5,727	5,726
Total, High Performance Computing and Network Facilities	168,617	217,521	217,516

Description

The High Performance Computing and Network Facilities (Facilities) subprogram is responsible for delivering forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, addressing a range of science issues that include the function of living cells and the power of fusion energy.

The Facilities subprogram contributes to DOE missions by providing the high performance computing facilities and advanced networks that advance DOE science. High performance computers carry out trillions or even quadrillions (a million, billion or a one with fifteen zeros) of calculations each second - powerful enough to simulate complex physical, biological and chemical phenomena. ASCR computing facilities help scientists understand these complex processes at unprecedented levels of detail - from individual atoms for nanoscale engineering to the entire planet for global climate studies or even the vast reaches of the Universe to understand the nature of dark energy. These computers, and the other research facilities of the Office of Science (SC), turn out many petabytes (a quadrillion bytes) of data each year. Moving this data to the researchers who need it requires advanced networks and related technologies also provided through the Facilities subprogram.

Supporting Information

To maintain leadership in areas of scientific modeling and simulation important to DOE missions, the Facilities subprogram plans, develops, and operates high performance computing facilities and advanced networks that are available—24 hours a day, 365 days a year—to researchers nationwide. This includes High Performance Production Computing at the National Energy Research Scientific Computing (NERSC) facility at Lawrence Berkeley National Laboratory (LBNL), Leadership Computing Facilities (LCFs) at Oak Ridge and Argonne National Laboratories, and the Energy Sciences Network (ESnet) managed by LBNL. The Facilities subprogram also invests in long-term needs through the Research and Evaluation Prototypes activity.

The Facilities subprogram computing resources are partially allocated through the Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program which provided 95 million hours of computing time in 2007. Eighty percent of the processor time on LCFs is allocated through INCITE to a small number of projects, each requiring a substantial amount of the available resources. A smaller percentage (~10%) of computing resources at NERSC and the Molecular Science Computing Facility at

Pacific Northwest National Laboratory, funded by the Biological and Environmental Research (BER) program, are also allocated through INCITE. These production computing facilities are more focused on the computing needs of the Office of Science and allocated through a competitive process reserved for researchers supported by the SC programs.

In 2007, INCITE research includes accelerator physics, astrophysics, chemical sciences, climate research, computer science, engineering physics, environmental science, fusion energy, life sciences, materials science, nuclear physics, and nuclear engineering. Practical applications of the research include designing quieter cars, improving commercial aircraft design, advancing fusion energy, studying supernova, understanding nanomaterials, studying global climate change, and the causes of Parkinson's disease.

Beginning in FY 2009, the ASCR computing facilities will develop and implement a unified approach to supporting and maintaining the software, languages, and tools that are critical to effective utilization of the machines.

Scientific Facilities Utilization

The ASCR program's FY 2009 budget request includes support to the NERSC, ESnet, and the LCFs, located at ORNL and ANL. The investment in NERSC will provide computer resources for about 2,500 scientists in universities, DOE laboratories, Federal agencies, and U.S. companies. The proposed funding will enable NERSC to maintain its role as one of the Nation's premier unclassified computing centers, a critical element for success of many SC research programs. The investment in ESnet will provide the DOE science community with capabilities not available through commercial networks or the commercial Internet. ESnet provides national and international high-speed access to DOE and SC researchers and research facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, supercomputers, and other high impact scientific instruments. The investment in LCFs will deliver unclassified high performance capability resources to scientific researchers. The proposed funding will allow the high performance resources at the ALCF to be upgraded to a peak capability of 250–500 teraflops by the end of FY 2008. The OLCF will be on a path to one petaflop peak capability by the end of 2008.

FY 2007 Accomplishments

- ***Leadership Computing Facility at Oak Ridge National Laboratory (OLCF) doubled XT capability to 119 teraflops.*** Users of the LCF's Cray XT3 supercomputer have recently received two substantial performance boosts, both linked to the arrival of a 68-cabinet Cray XT4 system capable of 65 teraflops. In December 2006, users were moved to the new system, gaining a 20 percent performance boost over the existing Cray XT3 system. The two systems were then connected, creating a system with a peak performance of 119 teraflops. Users were given access to this enormously powerful combined system in April 2007. Between the combined Cray XT system and the center's Cray X1E Phoenix supercomputer, users through DOE's Innovative and Novel Computational Impact on Experiment and Theory (INCITE) program were allocated 78.7 million processor hours in 2007 which more than doubled the processor hours available in 2006.
- ***Argonne Leadership Computing Facility established.*** The ALCF achieved significant progress in its major facility upgrade project at Argonne National Laboratory in FY 2007. Key milestones that were met include: successfully completing the cost and schedule review, validating the project plans, and establishing the project baseline. To meet DOE's scientific computing mission needs, the ALCF ordered a 100 teraflop Blue Gene/P system for delivery in 2007. To meet user support and operational needs, Argonne created a new Leadership Computing Facility division at Argonne, and

added staff—eleven by spring 2007—spanning computational science, applications performance, user services, operations and administration.

- ***National Energy Research Scientific Computer Center (NERSC) increased peak capacity by 500 percent.*** In 2007, NERSC, DOE's flagship high performance production facility at Lawrence Berkeley National Laboratory, accepted delivery of a 100 teraflop Cray Hood system consisting of over 19,000 AMD Opteron 2.6-gigahertz processor cores, with two cores making up one node. Each node has 4 gigabytes of memory resulting in an aggregate memory capacity of 39 terabytes. This computer will increase the resources available at NERSC for high performance capacity computing by 500%.
- ***Energy Sciences Network (ESnet) launched first segment of the next-generation nationwide scientific research network.*** The Department of Energy began operation of the first national ring of ESnet4 in September 2007. The first segment connects the Washington, D.C. area to New York and Chicago through a partnership between Internet2 and ESnet that was announced in August, 2006. The new network will initially operate on two dedicated 10 gigabit per second (Gbps) wavelengths on the new Internet2 nationwide optical infrastructure and will seamlessly scale over the next several years to meet the complex needs of large-scale DOE Office of Science research projects. Once completed, ESnet4 will be the most advanced and reliable, high capacity nationwide network supporting scientific research efforts of the DOE research community. By providing reliable high bandwidth access to DOE laboratories and other major research facilities, ESnet4 will enhance the capabilities of researchers and scientists across the country, and their international collaborators, to use large-scale instruments to advance the scientific mission of the Office of Science.
- ***Simulations on Cray XT4 Provide New Insights into Adsorption.*** Researchers from ORNL used the leadership supercomputers at Oak Ridge to significantly enhance our understanding of adsorption, the small-scale process by which one molecule attaches to another. The Oak Ridge team answered a question that has long vexed physical chemists, resolving the molecular structure of successive layers of methane as they attach to magnesium oxide. Their work was featured in January 2007 as the cover article in the *Journal of Physical Chemistry C*, a publication of the American Chemical Society that focuses on nanomaterials and surface science.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
High Performance Production Computing	**37,554**	**54,200**	**54,790**

This activity supports the NERSC facility located at LBNL. NERSC delivers high-end capacity computing services and support to the SC research community. Nearly 2,500 computational scientists, in about 400 projects, use NERSC to perform basic scientific research across a wide range of disciplines including astrophysics, chemistry, climate modeling, materials, analysis of data from high energy and nuclear physics experiments, investigations of protein structure, and a host of other scientific endeavors. NERSC users are primarily supported by the SC programs with 56% based in universities, 33% in National Laboratories, 7% in other government laboratories, and 4% in industry.

In 2007, the capacity of NERSC was expanded by 500 percent, with the acquisition of the 119 teraflop Cray XT4 system. FY 2009 funding will support the continued operation of the NERSC Cray XT4 system, and two clusters available for scientific applications that do not scale well to more than 512 processors and are therefore not well suited to the Cray architecture. These computational resources are integrated by a common high performance file storage system that enables users to easily migrate to any of the NERSC resources. With many petabytes of storage and an average transfer rate in the hundreds of megabytes per second this system also allows users to easily move data into and out of the NERSC facility.

In FY 2009, NERSC will continue to play a key role in the SC strategy for computational science because it enables teams to prepare to make use of the LCFs as well as to perform the calculations that are required by the missions of the SC programs. About 10% of the NERSC facility will be allocated through SC's Innovative and Novel Computational Impact on Theory and Experiment (INCITE) program.

	FY 2007	FY 2008	FY 2009
Maximum Hours	8,760	8,760	8,760
Scheduled Hours	8,585	8,585	8,585
Unscheduled Downtime	1%	1%	1%

Leadership Computing Facilities (LCF)	**94,910**	**110,158**	**115,000**

The LCF activity was initiated with a call for proposals in FY 2004. As a result of the peer-reviewed competition, the partnership established by ORNL, ANL, and PNNL was selected to provide capability computing resources for SC researchers.

▪ **Leadership Computing Facility at ORNL (OLCF)**	**77,000**	**83,716**	**85,000**

The first LCF capability for science was established in late FY 2005 at ORNL. In FY 2007, the OLCF upgraded the Cray XT3 with 11,708 dual-core processors providing a peak capacity of 119 teraflops. The Facility will be upgraded to a peak capacity of 250 teraflops by the end of 2007 by replacing the dual-core processors with quad-core processors. This upgrade will provide applications with valuable experience using a multi-core architecture. By the end of 2008, the facility will operate a one petaflop (1,000 teraflops) Cray Baker system expected to contain over 22,000 quad-core processors.

In FY 2009, the OLCF will continue to provide world leading high performance capability to researchers on a peer-reviewed basis through INCITE awards. Some of these applications, particularly in fusion and climate research, are achieving sustained performance in excess of 80 teraflops or nearly 70% of the peak capability. The acquisition of a 1 petaflop Cray Baker system in late 2008 will enable further scientific advancements, such as simulations of fusion devices that approach ITER scale. The success of this effort is built on the gains made in research and evaluation prototypes and the SciDAC program and on years of research in applied mathematics and computer science.

	FY 2007	FY 2008	FY 2009
Maximum Hours	7,008	7,008	7,008
Scheduled Hours	7,008	7,008	7,008
Unscheduled Downtime	1%	1%	1%

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
▪ **Leadership Computing Facility at ANL (ALCF)**	**17,910**	**26,442**	**30,000**

In FY 2007, further diversity with the LCF resources was realized with an acquisition by ANL of a high performance IBM Blue Gene P with low-electrical power requirements and a peak capability of over 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 facility provides many applications, including molecular dynamics and materials, with access to a system that is better suited to their computing needs.

In FY 2009 the ALCF will be operating the 500 teraflop IBM Blue Gene/P acquired in FY 2008. The facility will focus on utilizing the IBM Blue Gene architecture and assisting INCITE projects, pioneer applications, and tool and library developers. Strengthening the Argonne infrastructure in FY 2009 will be essential to prepare the facility, and the user community, for the more complex machine being developed through the joint research project with NNSA and IBM.

	FY 2007	FY 2008	FY 2009
Maximum Hours	3,000	6,000	7,008
Scheduled Hours	3,000	6,000	7,008
Unscheduled Downtime	1%	1%	1%

Research and Evaluation Prototypes	**14,313**	**23,100**	**17,000**

The Research and Evaluation Prototype activity addresses the challenges of the systems that will be available by the end of the decade. We anticipate that these systems will be significantly more complex than current systems. As a result, many of the tools and techniques we have developed will no longer be effective. By actively participating in the development of these next-generation machines, researchers will better understand the inherent challenges and can begin to work on overcoming those challenges. This activity will prepare researchers to effectively utilize the next generation of scientific computers and will also reduce the risk of future major procurements.

The Research and Evaluation Prototype activities will be carried out in close partnership with the NNSA and the DARPA HPCS program. This activity includes the DOE partnership in the DARPA HPCS Phase III program ($13,000,000) as well as support for SC's participation in the joint SC-NNSA partnership with IBM to explore and advance low power density approaches to petascale computing ($4,000,000).

High Performance Network Facilities and Testbeds	**21,840**	**24,336**	**25,000**

This activity supports operation and upgrades for the Energy Science network (ESnet) and a related research partnership with Internet2. The ESnet provides a high bandwidth network connecting DOE and SC researchers and research facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, supercomputers, and other high impact scientific instruments. Each year the amount of data generated by these facilities roughly doubles. To meet demand, ESnet has partnered with Internet2—the leading provider of university networks—to push the state-of-the-art and deliver next generation optical network technologies that greatly expand capacity in the core science networks.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

In FY 2009, ESnet, in partnership with Internet2, will continue to implement a next generation optical network infrastructure for U.S. science as announced in August 2006. ESnet will deliver 40–60 Giga (billion) bits per second (Gbs) connections to SC laboratories in FY 2009 on a path to achieving 160–400Gbs connectivity in FY 2010–FY 2011 when research efforts are expected to result in new technologies in the core network. Continued progress in high performance networks also builds on the tools and knowledge developed by the Next Generation Networks for Science research activity.

	FY 2007	FY 2008	FY 2009
Maximum Hours	8,760	8,760	8,760
Scheduled Hours	8,760	8,760	8,760
Unscheduled Downtime	0.01%	0.01%	0.01%

	FY 2007	FY 2008	FY 2009
Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR)	**—**	**5,727**	**5,726**

In FY 2007, $4,264,000 and $512,000 were transferred to the SBIR and STTR programs respectively. The FY 2008 and FY 2009 amounts shown are the estimated requirements for the continuation of the SBIR and STTR programs.

	FY 2007	FY 2008	FY 2009
Total, High Performance Computing and Network Facilities	**168,617**	**217,521**	**217,516**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
High Performance Production Computing	
The increase is due to increased operating costs for the NERSC facility.	+590
Leadership Computing Facilities (LCFs)	
The increase will support the installation, testing, and operation of a one petaflop Cray Baker system at the OLCF and a 500 teraflop IBM Blue Gene system at the ALCF, including user support activities at both facilities. This capability will accelerate scientific understanding in an array of research areas including: astrophysics, biology, climate change, fusion energy, materials, and chemistry.	+4,842
Research and Evaluation Prototypes	
The decrease is due to a decrease in the ASCR contribution to the DARPA HPCS program. In FY 2008, ASCR fully funded the DOE commitment to the DARPA HPCS program, including the NNSA portion of the effort. This budget request assumes that NNSA will resume participation in the DARPA HPCS effort in FY 2009.	-6,100

	FY 2009 vs. FY 2008 ($000)
High Performance Network Facilities and Testbeds	
The increase will enable ESnet to deliver 40–60 Gbs connections to SC laboratories in FY 2009. The increase in bandwidth is critical to meeting the growing requirements for Department applications and facilities.	+664
SBIR/STTR	
Decrease in SBIR/STTR due to small decrease in operating expenses.	-1
Total Funding Change, High Performance Computing and Network Facilities	**-5**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Capital Equipment	9,743	13,000	13,000

Biological and Environmental Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Biological and Environmental Research					
Biological Research	350,485	411,273	-3,743[a]	407,530	413,613
Climate Change Research	129,619	138,124	-1,257[a]	136,867	154,927
Total, Biological and Environmental Research	480,104[bcd]	549,397	-5,000[a]	544,397	568,540

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007"

Mission

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

Strategic and GPRA Unit Program Goals

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

Strategic Theme 3, Scientific Discovery & Innovation

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

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

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[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.
[b] Total is reduced by $13,311,000: $11,885,000 of which was transferred to the Small Business Innovative Research (SBIR) program and $1,426,000 of which was transferred to the Small Business Technology Transfer (STTR) program.
[c] Total includes $9,920,000 reprogrammed from prior year balances to support the GTL Bioenergy Research Centers.
[d] The Congressional control level in FY 2007 is at the Biological and Environmental Research level. Starting in FY 2008, it is at the Biological Research and Climate Change Research levels.

The BER program has one GPRA Unit Program Goal which contributes to Strategic Goals 3.1 and 3.2 in the “goal cascade”:

GPRA Unit Program Goal 03.1/2.48.00: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and facilitate the entrainment of physical sciences advances in the biomedical field.

Contribution to GPRA Unit Program Goal 03.1/2.48.00, Harness the Power of Our Living World

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

We intend to understand how living organisms interact with and respond to their environments to be able to use biology to produce clean energy, remove excess carbon dioxide from the atmosphere, and help clean up the environment. Our understanding of the causes and consequences of regional and global climate change and our ability to predict climate over decades to centuries at regional to global scales, enables development of science-based solutions to minimize the potential adverse impacts of climate change and to better plan for our Nation’s future energy needs and resource use. Understanding the biological effects of low doses of radiation can lead to the development of science-based health risk policy to better protect workers and citizens. Understanding the fate and transport of environmental contaminants can lead to improved decision making as well as the discovery of innovative approaches to remediate and monitor the environment.

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

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

In addition, BER plans, constructs, and operates reliable, scientific facilities to serve thousands of researchers at universities, national laboratories, and private institutions from all over the world. These include structural biology research beam lines at the synchrotron light sources and neutron sources; the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) (including the Molecular Sciences Computing Facility) which provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation; the Joint Genome Institute/Production Genomics Facility (JGI/PGF) for high-throughput DNA sequencing of non-medical microbes and plant targets; and the Atmospheric Radiation Measurement (ARM) facilities for climate change research.

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

Biological Research

- **Life Sciences:** Provide the fundamental scientific understanding of plants and microbes necessary to develop new robust and transformational basic research strategies for producing biofuels, cleaning up waste, and sequestering carbon.

- **Medical Applications:** Develop intelligent biomimetic electronics that can both sense and correctly stimulate the nervous system.[a]
- **Environmental Remediation:** Provide sufficient scientific understanding such that DOE sites would be able to incorporate coupled physical, chemical, and biological processes into decision making for environmental remediation and long-term stewardship.

Climate Change Research

- **Climate Change Research:** Deliver improved scientific data and models about the potential response of the Earth's climate and terrestrial biosphere to increased greenhouse gas levels for policy makers to determine safe levels of greenhouse gases in the atmosphere.

BER Facilities

- **Facilities:** Manage facilities operations to the highest standards of overall performance using merit evaluation with independent peer review.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Strategic Goal 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 03.1/2.48.00, Harness the Power of Our Living World			
Biological and Environmental Research	480,104	544,397	568,540

[a] This indicator is not a PART measure.

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 03.1/2.47.00 (Harness the Power of Our Living World)					
Biological Research					
Life Sciences					
Increase the rate of DNA sequencing: Produce at least 20 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2005 at least 28 billion base pairs will be sequenced. [Met Goal]	Increase the rate of DNA sequencing: Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2006 at least 30 billion base pairs will be sequenced. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing – Cost reductions will increase the number of high quality base pairs determined (less than one error in 10,000 bases) by 25% from the FY 2006 target of 582 base pairs per dollar to 781 base pairs per dollar. [Met Goal]	Increase the rate and decrease the cost of DNA sequencing – Increase by 10% the number (in billions) of high quality (less than one error in 10,000) bases of DNA from microbial and model organism genomes sequenced the previous year, and decrease by 10% the cost (base pair/dollar) to produce these base pairs from the previous year's actual results. FY08: 42.8 billion base pairs (bp) and 785bp/$1 (based on FY07 actual was 38.95 Billion base pairs (bp), and JGI achieving 714bp/$1.)	Increase the rate and decrease the cost of DNA sequencing – Increase by 10% the number (in billions) of high quality (less than one error in 10,000) bases of DNA from microbial and model organism genomes sequenced the previous year, and decrease by 10% the cost (base pair/dollar) to produce these base pairs from the previous year's (FY08) actual results.
Medical Applications[a]					
Advance blind patient sight: Complete fabrication of 60 microelectrode array for use as an artificial retina and tested in animal subject. [Met Goal]	Advance blind patient sight: Complete testing on a 60 microelectrode array artificial retina and insert prototype device into a blind patient. [Goal Not Met]	Advance blind patient sight: Begin testing of prototypes for 256 microelectrode array artificial retina. [Met Goal]	Advance blind patient sight: complete design and construction of final 256 electrode array. Begin in vitro testing and non-stimulating testing in animals. [Met Goal]	Advance blind patient sight: Complete in vitro testing of 256 electrode array and continue animal studies of final design 256 electrode array.	Advance blind patient sight: Complete in vitro and in vivo studies of final design 256 electrode device. Submit test data to FDA for approval of 256 electrode array for human studies.

[a] This is not a PART measure.

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
Environmental Remediation					
Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales: Quantify contaminant immobilization and remobilization by different factors: 1. natural microbial mechanisms; 2. chemical reactions with minerals; and 3. colloid formation. [Met Goal]	Determine scalability of laboratory results in field experiments—Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings. [Met Goal]	Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests. [Met Goal]	Implement a field-oriented, integrated experimental research program to quantify coupled processes that control reactive transport of at least one key DOE contaminant. [Met Goal]	Determine scalability of laboratory results in field environments—Determine the dominant processes controlling the fate and transport of contaminants in subsurface environments and develop quantitative numerical models to describe contaminant mobility at the field scale. For FY 2008: Identify the critical redox reactions and metabolic pathways involved in the transformation/ sequestration of at least one key DOE contaminant in a field environment.	Determine scalability of laboratory results in field environments—Determine the dominant processes controlling the fate and transport of contaminants in subsurface environments and develop quantitative numerical models to describe contaminant mobility at the field scale. For FY 2009: Test geophysical techniques that measure parameters controlling contaminant movement under field conditions in at least two distinct subsurface environments.
Climate Change Research					
Improve climate models: Implement a model test bed system to incorporate climate data rapidly into climate models to allow testing of the performance of sub-models (e.g., cloud resolving module) and model parameters by comparing model simulations with real world data from the ARM sites and satellites. [Met Goal]	Improve climate models: Implement three separate component submodels (an interactive carbon cycle submodel, a secondary sulfur aerosol submodel, and an interactive terrestrial biosphere submodel) within a climate model and conduct 3-4 year duration climate simulation using the fully coupled model. [Met Goal]	Improve climate models: Produce a new continuous time series of retrieved cloud properties at each ARM site and evaluate the extent of agreement between climate model simulations of water vapor concentration and cloud properties and measurements of these quantities on the timescale of 1 to 4 days. [Met Goal]	Provide new mixed-phase cloud parameterization for incorporation in atmospheric GCMs and evaluate extent of agreement between climate model simulations and observations for cloud properties in the arctic. [Met Goal]	Improve climate models—Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate. FY 2008: Report results of decade-long control simulation using geodesic grid coupled climate model and produce new continuous time series of retrieved cloud, aerosol, and dust properties, based on results from the ARM Mobile Facility deployment in Niger, Africa.	Improve climate models—Develop a coupled climate model with fully interactive carbon and sulfur cycles, as well as dynamic vegetation to enable simulations of aerosol effects, carbon chemistry, and carbon sequestration by the land surface and oceans and the interactions between the carbon cycle and climate. FY 2009: Provide improved climate simulations on subcontinental, regional, and large watershed scales, with an emphasis on improved simulation of precipitation and produce new continuous time series of retrieved cloud, aerosol, and radiation for Arctic region.

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
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 (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 90% of the total scheduled annual operation time for each group of facilities. [Met Goal]	Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 95% of the total scheduled annual operation time for each group of facilities. [Met Goal]	Maintain and operate BER facilities (Life Science—PGF and the Mouse facility; Climate Change Research—ARM and FACE; and Environmental Remediation—EMSL) such that achieved operation time is on average greater than 98% of the total scheduled annual operation time for each group of facilities. [Met Goal]	The achieved operation time of the scientific user facility (Life Science—PGF; Climate Change Research—ARM; and Environmental Remediation—EMSL) as a percentage of the total scheduled annual operating time is greater than 98%.	The achieved operation time of the scientific user facility (Life Science—PGF; Climate Change Research—ARM; and Environmental Remediation—EMSL) as a percentage of the total scheduled annual operating time is greater than 98%.

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. Within the Biological Research subprogram, of highest priority will be the Genomics: GTL program which develops an understanding of the fundamental principles underlying the function and control of biological systems. This approach of well-integrated, technology based, interdisciplinary research teams will facilitate the study of complex biological systems to solve problems in energy production and environmental cleanup. As part of this approach to biological research, the GTL Bioenergy Research Centers were initiated in FY 2007 and will be fully operational in FY 2008.

BER priorities within the Climate Change Research subprogram are to develop the ability to predict climate on global and regional scales; to explore the impacts of excess atmospheric CO_2 on the Earth system; to develop strategies for its removal and sequestration from the atmosphere; and, provide the science to underpin the prediction of the impacts of climate change. These priorities will depend on the continued development of novel research tools and a close integration of experimental, observational, and computational research.

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

All BER-supported research projects undergo regular peer review and merit evaluation based on procedures established 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 (e.g., the basic research needs of the energy technology programs within DOE) and SC mission statements and strategic plans; (2) evolving scientific opportunities that sometimes revolutionize disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or subfields, such as those performed by the National Academy of Science; (4) unanticipated failures or unexpected developments, 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 organizations (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], Nuclear Regulatory Commission [NRC], Department of Agriculture [USDA], the Department of State (DOS), and the Department of Defense [DOD]). BER Climate Change Research is coordinated with the U.S. Global Change Research Program, an interagency program codified by Public Law 101-606 and involving thirteen federal agencies and departments.

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

Validation and Verification

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

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The Biological and Environmental Research program has incorporated feedback from OMB into the FY 2009 Budget Request and will continue to take the steps necessary to improve performance.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the BER program a score of 86% overall which corresponds to a rating of "Effective". The assessment found that BER had developed a limited number of adequate performance measures which are continued for FY 2009. These measures have been incorporated into this Budget Request, BER grant solicitations, the performance plans of senior managers and are considered in routine decisions for research funding within the Program. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. Roadmaps, developed in consultation with the Biological and Environmental Research Advisory Committee (BERAC), will guide triennial reviews by BERAC of progress toward achieving the long term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

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

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

  The National Research Council (NRC) reviewed the design of the Genomics: GTL program and its infrastructure plan. The NRC committee recommended that the GTL facilities should be focused not on particular technologies, but on research underpinning particular applications—bioenergy, carbon sequestration, or environmental remediation.

  In response to the NRC recommendations, the Office of Science revised its original single-purpose user facilities plan to develop and support vertically-integrated GTL Research Centers to accelerate systems biology research. The vertically-integrated GTL Research Centers will not require construction of facilities. The first three research centers, selected and implemented in FY 2007, have a focus on bioenergy research; subsequent centers will focus on carbon sequestration and environmental remediation.

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

  In response, BER is using external panels (Committee of Visitors – COVs) to review the quality, relevance, and performance of its research portfolio and grant management practices. COVs findings and BER responses can be viewed at http://www.sc.doe.gov/measures/FY06.html and http://www.sc.doe.gov/measures/FY07.html

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

  BER conducted reviews of the Joint Genome Institute Production Genomics Facility (JGI/PGF), EMSL facilities, and the ARM facilities.

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

Basic and Applied R&D Coordination

Carbon Dioxide Capture and Storage: BER is requesting $17,374,000 to support basic research in carbon dioxide (CO_2) capture and storage. This R&D integration focus area was the subject of four DOE workshops, including:

- Carbon Sequestration Research and Development (December, 1999—Jointly sponsored by the Office of Fossil Energy and Office of Science),
- Computational Subsurface Sciences Workshop Report (January, 2007),
- Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems (February, 2007), and
- Carbon Sequestration Technology Roadmap and Program Plan 2007 (May 2007, Office of Fossil Energy).

The workshops support the need for additional research emphasis in CO_2 capture and storage to benefit the optimization of fossil fuel power generation and the development of carbon neutral fuels. The BER research includes understanding, modeling, and predicting the processes that control the fate of carbon dioxide injected into geologic formations, subsurface carbon storage, and the role of microbes and plants in carbon sequestration in both marine and terrestrial environments. Such research could increase the likelihood for success in DOE strategic initiatives since achieving the goal of net-zero carbon emissions from fossil fuel usage requires efficient and cost-effective capture of CO_2 as well as safe and reliable storage, which poses substantial science and technology challenges.

Applied technology offices within DOE that could benefit from the carbon dioxide capture and storage research integration effort include: the Offices of Fossil Energy and Energy Efficiency and Renewable Energy (for development of biofuels).

Characterization of Radiological Waste: BER is requesting $1,500,000 to support basic research in characterization of radiological waste. This R&D integration focus area was included as a subject area in six DOE workshops, including:

- Basic Research Needs for Advanced Nuclear Energy Systems (July 2006—NE, BES),
- Nuclear Physics and Related Computational Science R&D for Advanced Fuel Cycles Workshop (August 2006—NE, NP, ASCR),
- EM Technical Integration Workshop: Reducing Technical Uncertainty in Clean-up Operations (October 2006—EM),
- Computational Subsurface Sciences Workshop (January 2007—ASCR, EM, FE, RW),

- Basic Research Needs for Geosciences: Facilitating 21st Century Energy Systems (February 2007—BES), and
- National Academy of Sciences: Science and Technology Needs for DOE Site Cleanup, EM Roadmap (March 2007—EM).

The workshops support the need for additional research emphasis in the characterization of radiological waste to address critical unanswered scientific questions to facilitate the stabilization, long-term storage, treatment, and ultimate disposal of radioactive waste.
The BER research effort addresses processes that control the mobility of radiological waste in the environment. This research will increase the likelihood for success in DOE strategic initiatives for clean up of legacy nuclear wastes and nuclear energy applications.

Applied technology offices within DOE that will benefit from the characterization of radiological waste research integration effort include: Offices of Environmental Management, Civilian Radioactive Waste Management, Legacy Management, and Nuclear Energy.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Carbon Dioxide Capture And Storage			
Biological Research	12,980	12,127	12,627
Climate Change Research	3,861	4,747	4,747
Total Carbon Dioxide Capture And Storage	16,841	16,874	17,374
Characterization of Radiological Waste			
Biological Research	—	—	1,500
Total Basic and Applied R&D Coordination	16,841	16,874	18,874

Overview

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

The Challenges

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

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, including radiochemistry, have the potential to revolutionize all of medical imaging with increases in resolution and sensitivity, ease of use, and patient comfort. Furthermore, understanding the biological effects of low doses of radiation will lead to the development of science-based health risk policy to better protect workers and citizens.

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

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

Significant Program Shifts

- The BER program has been restructured, as directed by Congress, into two separate sub programs—Biological Research and Climate Change Research. Biological Research includes activities in Life Sciences, Medical Applications, and Environmental Remediation Research.
- Radiopharmaceuticals and Imaging activities renamed as Radiochemistry and Instrumentation and moved from Medical Applications to Life Sciences.

Biological Research

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Biological Research			
Life Sciences	252,502	294,681	296,206
Medical Applications	6,584	8,226	8,226
Environmental Remediation	91,399	93,764	98,383
SBIR/STTR	—	10,859	10,798
Total, Biological Research	350,485	407,530	413,613

Description

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. Within the Biological Research subprogram, of highest priority will be the Genomics: GTL program which develops an understanding of the fundamental principles underlying the function and control of biological systems. This approach of well-integrated, technology based, interdisciplinary research teams will facilitate the study of complex biological systems to solve problems in energy production and environmental cleanup. As part of this approach to biological research, the GTL Bioenergy Research Centers were initiated in FY 2007 and will be fully operational in FY 2008.

Fundamental research in Genomics: GTL, systems biology, and the health effects of low dose radiation are used to understand why some people are more sensitive to low doses of radiation and how plants and microbes can be used to produce clean energy, remediation or stabilize wastes *in situ*, or sequester excess atmospheric carbon dioxide. New radiotracers and imaging technologies and reagents are developed for the biological and environmental research communities. Research on contaminant transport, novel remediation methods and cutting edge molecular tools for investigating and monitoring environmental processes are expected to reduce the costs, risks, and schedules for the cleanup and monitoring of the DOE nuclear weapons complex and to provide knowledge for a broad range of remediation problems, including avoidance of environmental hazards for future nuclear energy options and geologic sequestration of excess atmospheric carbon. New, research-based, strategies and tools are already being deployed by the offices of Environmental Management and Legacy Management. Scientific user facilities are made available for determining high-resolution protein structures at DOE synchrotrons and neutron sources; for high-throughput genomic DNA sequencing of microbes, microbial communities, and complex organisms such as plants at the Joint Genome institute; and for the environmental molecular sciences at the Environmental Molecular Sciences Laboratory.

The Biological Research subprogram continues a substantial involvement of academic scientists along with the scientists at the national laboratories.

Periodic retrospective analysis will be employed to evaluate research directions, the accumulation of knowledge, and to validate specific outcomes. Biological Research activities have been reviewed by a BERAC Committee of Visitors (COV) and future reviews are scheduled. In FY 2005, Life Sciences activities were reviewed and the next scheduled review of Life Sciences activities will be in FY 2008. For the Medical Applications activities, a COV was originally planned for FY 2006. This review has been delayed pending the completion of the National Academy of Science (NAS) review of U.S. nuclear medicine research and will be combined with the scheduled review of the Life Sciences activities in FY 2008. Environmental Remediation activities were reviewed by a BERAC COV in FY 2005 with another COV review planned for FY 2008. The BERAC COV reports and the BER responses are at http://www.science.doe.gov/ober/berac.html.

FY 2007 Accomplishments

- **Surveying New Protein Families:** The Global Ocean Survey (GOS) project performed metagenomic sampling from diverse aquatic environments—including estuaries, lakes, and open ocean sites. The analysis of the geographically diverse environmental genomic data set of 6.3 billion base pairs—twice the size of the human genome and vastly larger than the initial Sargasso Sea data set—has resulted in the development and use of a new, improved method for assembling the sequence data. The new method of assembly, allows robust genomic comparison and inference of genetic adaptation in response to specific environmental conditions; and the development of a powerful new computational algorithm to predict protein function from metagenomic sequence data. The new protein prediction tool revealed an astonishingly high number of new proteins from the GOS data, and demonstrates the significant value of metagenomic studies in gene and protein function discovery.
- **Evidence for Non-Linear Dose Responses**: New research from the Low Dose Radiation Program has demonstrated that following exposures to low doses of radiation there are unique dose-dependent changes in gene and protein expression which differ from those seen after high dose exposures. Low dose activation of such mechanisms supports the existence of non-linear dose-response relationships for low-LET (linear energy transfer) radiation. Identification of these genes is providing a scientific basis for defining metabolic pathways activated by radiation and determining mechanisms of action. The magnitude of the response for these phenomena has been shown to be dependent on the genetic background of the cells, tissues and organisms in which they are being measured.
- **Simultaneous PET/MRI Instrument Development:** The first truly simultaneous hybrid PET/MRI scanner, based on an all-solid state detector contained in the Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI) insert has been developed. This novel BER-funded PET/MRI imaging technology can provide simultaneous quantitative functional information about receptor occupancy or enzyme concentration (from PET) and high resolution structural/anatomical data (from MRI) for research purposes in animals, and eventually perhaps human subjects, *in vivo*. In this way, structural and functional information about the same cells can be obtained and correlated.
- **EMSL Magnetic Resonance Users Develop Method to Quantify Radiation Damage in Nuclear Waste Containment Material:** EMSL users have developed a method to analyze the stability of proposed waste encapsulation forms. Encapsulation of nuclear waste into various crystalline solids such as zircon is proposed as one method to immobilize wastes for long term storage. However, methods to directly assess the effects of prolonged radiation exposure on the stability of these crystalline solids have remained elusive. Using EMSL's solid state nuclear magnetic resonance (NMR) spectrometry capabilities researchers have been able to evaluate the effects of radiation on the stability of one proposed crystalline encapsulation material. The technique allows designers to assess rates of degradation of crystalline materials in order to improve the design and performance of waste encapsulation forms.
- **BER Environmental Remediation research contributes to savings for the cleanup of Rocky Flats:** Research established that a colloid-based mechanism for plutonium and americium mobility

existed in surface soils and sediments at the Rocky Flats site rather than an aqueous sorption-controlled mechanism. This result provided the scientific basis for understanding the nature of the threat posed by these contaminants. The research allowed contractors to shift focus towards implementing soil erosion control strategies rather than groundwater remediation strategies to prevent the transport of contaminants saving billions of dollars in cleanup costs at the site. The science-based approach was featured late in 2006 in the journal *Physics Today.*

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Life Sciences	**252,502**	**294,681**	**296,206**
▪ **Structural Biology**	**15,722**	**15,300**	**15,300**

In FY 2009, the Structural Biology program continues to develop and support access to beamlines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and the NSF, the management and maintenance of 22 experimental stations at several DOE synchrotrons (Advanced Photon Source [APS], Advanced Light Source [ALS], and Stanford Synchrotron Radiation Laboratory [SSRL]). User statistics for all BER structural biology user facilities are included in the Basic Energy Sciences (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. Fundamental science related to protein structure and instrument development is also supported at the beamlines.

▪ **Molecular and Cellular Biology**	**145,879**	**177,421**	**190,464**
• **Carbon Sequestration Research**	**7,480**	**7,127**	**7,127**

Microbes and plants play substantial roles in the cycling of carbon through the environment. Carbon sequestration research seeks to understand the fundamental mechanisms of carbon fixation, conversion and cycling in microbes, microbial communities, and plants. The program has initiated a new focus on carbon sequestration and utilization for biofuels, with genomics-based research that will lead to the improved use of plant feedstocks for the production of carbon-neutral fuels such as ethanol or renewable chemical feedstocks. This is part of the BER contribution to the Climate Change Technology Program (see the Climate Change Research subprogram for additional information). Systems biology approaches are supported to yield fundamental knowledge of the structure, function, and organization of plant genomes leading to increased carbon fixation and biomass yield, improved feedstock characterization and sustainability. In FY 2009 fundamental research focuses on understanding carbon uptake, fixation, and storage in plants and soil and marine microbes, strongly leveraging the increasing availability of information from whole organism genomes and community metagenomes. Research will also focus on understanding the role that microbial communities or plant-microbe associations play in the transfer of carbon between the roots and the soil, to identify strategies that would lead to increased carbon storage in the root zone environment and surrounding soil. This research leverages BER's fundamental microbial systems biology research in Genomics: GTL and BER's terrestrial carbon cycle research to evaluate options for molecular-based terrestrial carbon sequestration and contributes to the President's Advanced Energy Initiative

	FY 2007	FY 2008	FY 2009
(AEI).			
• **Genomics: GTL**	**121,000**	**152,713**	**162,731**
► **Genomics: GTL Foundational Research**	**43,023**	**37,713**	**42,731**

(dollars in thousands)

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

In FY 2009, the program continues to support a mix of approximately eight large multidisciplinary research teams and 30 smaller individual investigator projects to:

- develop innovative high-throughput genomic and analytic strategies and research tools for improving plant biomass and for the subsequent microbial conversion of plant biomass to biofuels: fundamental research that will contribute to GTL Bioenergy Research Centers and to GTL Bioethanol research;
- develop novel technologies to characterize the internal environment, subcellular architecture and metabolism of microbes: fundamental research that will contribute to GTL Bioenergy Research Centers and to GTL Bioethanol and Biohydrogen research; and
- develop genomic, metabolic, and imaging technologies to study the structure and function of microbial communities with respect to fate and transport of environmental contaminants, bioenergy production, and the fate and flow of carbon through terrestrial and marine environments.

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

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

In FY 2009, increased funding to GTL SciDAC research will initiate new research to develop mathematical and computational tools needed to model, through computer programs, genomic changes to plants and microbes. This new computational capability is expected to enable the more economical design, development and improvement of desirable

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

properties of specific enzymes, metabolic pathways, and whole organisms to enable more efficient conversion of sunlight to biomass and biomass to biofuels as well as to better predict the quantitative role of plants and microbes in the Earth's complex biological carbon cycle.

Over the long-term, the GTL Foundational Research will provide the scientific knowledge base and technology that can accelerate progress in all aspects of the Genomics: GTL program, as well as bridge to other DOE offices such as Energy Efficiency and Renewable Energy, Fossil Energy, and Environmental Management to develop biotechnology solutions for DOE energy and environmental needs. The program focuses on interdisciplinary scientific challenges that can be uniquely addressed by DOE and its national laboratories in partnership with scientists at universities and in the private sector.

	FY 2007	FY 2008	FY 2009
► **Genomics: GTL Sequencing**	**10,000**	**10,000**	**10,000**

DNA sequence data underpins and is the starting point for all aspects of the Genomics: GTL program. The vast majority of high-throughput DNA sequencing of plants, microbes, and microbial communities conducted at the JGI/PGF user facility is directly relevant to the Genomics: GTL program. In FY 2009, research will continue within Genomics: GTL to generate DNA sequence data of individual genes as they are expressed, whole genomes, and metagenomes in order to provide essential information needed to formulate genetic engineering strategies for microbes and plants, to understand plant and microbe molecular machines, to determine the composition of complex microbial communities, and to dissect plant-microbe associations. The DNA sequencing done in this activity is accomplished at JGI/PGF and complements the broader DNA sequencing activities conducted at the JGI/PGF and will specifically provide genetic data to projects within the Genomics: GTL activity. The DNA sequencing needs of the DOE Bioenergy Centers will be supported within this activity.

	FY 2007	FY 2008	FY 2009
► **Genomics: GTL Biohydrogen Research**	**19,334**	**15,000**	**15,000**

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

This activity supports innovative systems biology research with a specific emphasis on biological hydrogen production, such as the discovery and development of improved or oxygen-tolerant hydrogenases, characterization of specific cellular architecture to facilitate electron transfer for optimum hydrogen production, and the redirection of metabolic pathways and metabolite flow into hydrogen production. While this activity draws upon the foundational research and technology development within the broader GTL portfolio, it is specifically directed towards scientific issues and challenges unique to biological hydrogen production. In FY 2009 research will continue on understanding key metabolic pathways in order to enhance microbial biohydrogen production.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
► **Genomics: GTL Bioethanol Research**	**18,723**	**15,000**	**20,000**

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

While this activity draws upon the foundational research and technology development within the broader GTL portfolio it is specifically directed towards scientific issues and challenges unique to understanding the metabolic conversion of 5- and 6-carbon sugars to ethanol. In FY 2009, research will support understanding of mechanisms that control glycolytic flux, analysis, and rational design of more robust ethanolgenic biocatalysts. The increased funding in FY 2009 will support peer-reviewed research to identify microorganisms in nature that retain glycolytic and fermentative activity in the presence of high ethanol concentrations, and engineer ethanol tolerant organisms to produce ethanol. These activities will be coordinated with the three DOE Bioenergy Centers to facilitate development of reagents of general use for the entire GTL research activity.

► **Genomics: GTL Bioenergy Research Centers**	**29,920**	**75,000**	**75,000**

GTL Bioenergy Research Centers will contribute to the President's Advanced Energy Initiative. The Research Centers will conduct fundamental biological research and, with this funding, involve no construction of facilities. The three Bioenergy Research Centers, all involving academic, industrial, and national lab scientists, are designed to accomplish the GTL program objectives more effectively. The centers will serve as catalysts for innovation and change, by concentrating appropriate technologies and scientific expertise to go from the genome sequence to an integrated systems understanding of the pathways and internal structures of plants and microbes most relevant to the steps required to develop bioenergy compounds.

The first three GTL Bioenergy Research Centers were selected and initiated in late FY 2007 following the issuance of a competitive funding opportunity announcement on August 1, 2006 and site selection according to merit-based peer review criteria. The three centers are: The Joint BioEnergy Institute at Lawrence Berkeley National Laboratory; The Great Lakes Bioenergy Research Center at the University of Wisconsin at Madison; and the BioEnergy Science Center at the Oak Ridge National Laboratory. In FY 2009, the three Bioenergy Centers are fully supported at approximately $25,000,000 each.

Research at the Centers will focus on developing the science underpinning biofuel production that will ultimately lead to technology deployable in the Nation's energy economy. A major emphasis will be on development of cost-effective strategies to convert plant biomass to ethanol, and potentially, production of biodiesel, hydrogen, methane, and biofuels for aviation. The Centers will develop new technologies but also draw on technology and basic science generated in the foundational research, biohydrogen, and bioethanol Genomics: GTL activities. The research programs in the Centers will be distinguished from those activities by being broader in scientific scope and in having multiple, coordinated disciplines focusing on the specific scientific goals of the centers. The research at the Centers will:

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

The Centers will be held to both intermediate and long term (i.e., develop innovative industrial ethanol producing methodologies) scientific deliverables to ensure that they will help meet the longer-term goals (i.e., genetically engineered model plants) of the Advanced Energy Initiative.

	FY 2007	FY 2008	FY 2009
• **Low Dose Radiation Research**	**17,399**	**17,581**	**20,606**

The goal of the Low Dose Radiation Research activity is to support research that will help determine health risks from exposures to low levels of ionizing radiation; information critical to adequately and appropriately protecting individuals, and to making more effective use of our national resources. Information developed in this program will provide a better scientific basis for making decisions with regard to remediating contaminated DOE sites and for determining acceptable levels of human health protection, both for cleanup workers and the public, in the most cost-effective manner. Some research in this program is jointly funded with NASA's Office of Biological and Physical Research.

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

In FY 2009, the program is 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 what causes some individuals to be more sensitive to radiation than others. Comparative genomics will afford new opportunities for identification of specific genetic markers within affected cell populations.

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

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
▪ **Human Genome**	**69,736**	**72,733**	**70,000**
• **Joint Genome Institute, Production Genomics Facilities**	**53,397**	**60,000**	**55,000**

The Joint Genome Institute's (JGI) high-throughput DNA sequencing factory, the Production Genomics Facility (PGF) is focused on helping to meet the demand for DNA sequencing in the broader energy and environment scientific community. Funding will be decreased in FY 2009, reflecting a transition in emphasis to research in Tools for DNA Sequencing and Sequence Analysis (see below). The JGI functions as a user facility for universities, National laboratories, and the Bioenergy Research Centers. All sequencing is on plants and microbes within the DOE science mission. The JGI's Community Sequencing Program (CSP) devotes all of its sequencing capacity to the merit-reviewed sequencing needs of the broader scientific community, while addressing the DOE mission-relevant criteria of energy production, carbon sequestration research and bioremediation research, and low dose radiation research.

In FY 2009, the CSP will sequence DNA from individual microbes, microbial communities, and small and large plants that will be selected by the CSP's merit review panel in FY 2008. A Laboratory Science Program that was initiated in FY 2007 has successfully expanded participation in genomic-based research at the DOE national laboratories and will be integrated with the CSP.

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

In November 2005, BERAC conducted a comprehensive review of the science, management, and operations of the DOE JGI/PGF. The committee gave high marks to the JGI with respect to scientific vision, the implementation of the role of the JGI as a user-facility and its focus on DOE mission objectives, and to the PGF for its state of the art operations with respect to cost, quality, and quantity of sequences that it produces. The JGI/PGF Will be next reviewed in the Fall of 2008.

	FY 2007	FY 2008	FY 2009
	(estimated)		
Optimal hours	8,400	8,400	8,400
Scheduled hours	8,400	8,400	8,400
Operation Time	>98%	>98%	>98%
Users[a]	120	120	120

• **Tools for DNA Sequencing and Sequence Analysis**	**14,339**	**7,733**	**10,000**

BER continues to develop the tools and resources needed by the scientific, medical, and

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[b]All PGF 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. Additionally, different users reflect vastly differing levels of JGI resources.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

industrial sector communities to fully exploit the information contained in complete DNA sequences, from energy-relevant microbes to low dose radiation effects. Use of sequence information to understand human biology and health effects will also require new strategies and tools capable of high-throughput, genome-wide experimental and analytic approaches. BER will continue efforts to develop high-throughput approaches for analyzing gene regulation and function.

In FY 2009, the increased funding will support efforts to develop high-throughput annotation methods and DNA sequencing research that addresses unique sequencing challenges primarily attributable to the complexity or difficulty of the environments from which the microbes or plants were isolated, as well as to the increasing difficulty of assembly of highly repetitive complex plant genomes.

• **Ethical, Legal, and Societal Issues (ELSI)**	**2,000**	**5,000**	**5,000**

BER ELSI research will continue the transition to activities applicable to Office of Science issues in bioenergy, synthetic biology, and nanotechnology, including exploration of, and communication of, the societal implications arising from these programs. The ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies will be studied. The research is coordinated across the Office of Science and with other relevant Federal agencies and offices (e.g., EPA, NSF, and OSTP).

In FY 2009, activities will continue to support peer-reviewed research on intellectual property and commercialization issues, economic impacts of sustainable agriculture-based biofuels, including land-use patterns, biorefineries, public perceptions of synthetic biology and nanotechnology applications, and support activities exploring the societal implications of research to be carried out by and at the BES Nanoscience Centers. The funding will continue to support ELSI research on the ecological and environmental impacts of nanoparticles (including nanotracers) resulting from nanotechnology applied to energy technologies.

▪ **Health Effects**	**7,378**	**7,321**	**7,321**

Health effects research in functional genomics provides a link between human genomic sequencing and the development of information that is useful in understanding normal human development and disease processes including susceptibility to low doses of ionizing radiation. The mouse continues to be a vital experimental tool for this understanding. The Center for Comparative and Functional Genomics ("Mouse House") at Oak Ridge National Laboratory serves as a national focal point for high-throughput genetic studies using mice. The Mouse House creates and genetically characterizes new mutant strains of mice that serve as important models of human genetic diseases and for understanding gene function. It also develops high-throughput tools and strategies to characterize these mice.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

In FY 2009, research will continue at the Laboratory for Comparative and Functional Genomics related to low dose radiation. However, beginning in FY 2008, BER no longer funds the Mouse House as a user facility. BER's programmatic need for this facility as a resource for understanding the human genome ended with the completion of human genome related research and the growth of the GTL program. However, there is still a broad need for mouse genetic resources in the scientific community, especially at the National Institutes of Health.

The research activities are principally carried out at national laboratories and selected through merit-review processes

▪ **Radiochemistry and Instrumentation**	**13,787**	**21,906**	**13,121**

In FY 2009, BER continues to support basic research that builds on unique DOE capabilities in physics, chemistry, engineering, and computational science. It supports fundamental imaging research, maintains core infrastructure for imaging research and development, including innovative imaging technology with respect to new radiochemistry and radiotracer methodologies for precise and dynamic metabolic imaging of biological organisms. This research will provide the capability to visualize plant and microbial metabolic networks and regulatory systems underlying cellular differentiation, specialization, and interactions with the environment.

The FY 2009 funding will support the development of peer-reviewed, multidisciplinary programs in radiochemistry at national laboratories and universities. These activities will provide for continuance and enhancement of core capabilities in radiochemistry while providing an extended framework for use of these capabilities to understand DOE mission areas in biological and environmental research. The decreased funding in FY2009 reflects the completion of awake animal imaging studies and pilot radiochemistry instrumentation projects initiated in FY2008.

Medical Applications

▪ **Artificial Retina**	**6,584**	**8,226**	**8,226**

In FY 2009, BER continues to utilize the resources of the national laboratories in material sciences, engineering, microfabrication, and microengineering to develop unique neuroprostheses and continue development of an artificial retina to restore sight to the blind. DOE's goal for the artificial retina project is to develop the technology and fabricate a 1,000+ electrode intraocular device that will allow a blind person to read large print, recognize faces, and move around without difficulty. In FY 2009 BER will support continued testing of a completely fabricated 240+ electrode retinal device. The DOE-sponsored phase of this effort will be completed in FY 2010.

Environmental Remediation	**91,399**	**93,764**	**98,383**
▪ **Environmental Remediation Sciences Research**	**43,496**	**46,665**	**48,485**

Environmental Remediation Sciences research activities address questions of fundamental environmental remediation science at the interfaces of biology, chemistry, geology, and physics. The research will help to provide the scientific foundation for the solution of key environmental challenges within DOE's cleanup mission at scales ranging from molecular to the field, including issues of fate and transport of contaminants in the environment; novel strategies for *in situ* remediation; and long-term monitoring of remediation strategies.

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

Remediation of subsurface contamination is a particularly challenging environmental problem for many DOE sites. In many cases the depth, area extent, and unique chemical characteristics of the contaminants is such that there are few remediation options available. In order to make sound, science-based decisions for dealing with subsurface contamination at DOE sites the Environmental Remediation Sciences activity funds research to: 1) understand the chemical nature of DOE-relevant contaminants; 2) understand the physical, chemical and biological processes that affect contaminant mobility in the subsurface; 3) detect the extent of contamination in the environment; 4) model and predict the mobility of contaminants in the subsurface, and; 5) devise remediation methods to remove or immobilize contaminants in the subsurface. This suite of research spans many scientific disciplines including chemistry, biology, geology, engineering and physics, and relies on integrative approaches to problem solving.

The goal of this integrative research effort is to develop accurate predictions of contaminant mobility in the subsurface under a variety of conditions, including remediation conditions, to allow DOE to make science-based decisions for environmental remediation or long term stewardship. In order to achieve this goal, research within the Environmental Remediation Sciences activity must link laboratory-derived results with processes observed in the environment. In addition to numerous laboratory-based projects at both academic institutions and national laboratories, FY 2009 funding supports three field research sites at Oak Ridge, Tennessee; Hanford, Washington; and Rifle, Colorado (a uranium mill tailings site). These field sites span a range of hydrogeochemical conditions and provide researchers opportunities to obtain sediment samples from DOE sites for further evaluation in the laboratory and to test laboratory-derived hypotheses regarding contaminant transport or remediation in the field under real world conditions. These field sites also are important for iterative testing and evaluation of computer models that will lead to more accurate descriptions of contaminant mobility in the environment.

Environmental Remediation Sciences research will continue to foster interdisciplinary research and be responsive to new knowledge and to advanced computational and analytical tools that emerge from research at the EMSL, the SciDAC program, the synchrotron light sources, the newly-commissioned Spallation Neutron Source, and from within the GTL program in support of DOE's clean-up mission.

FY 2009 support for SciDAC research is intended to provide advanced models to better understand the movement of subsurface contamination. This will benefit environmental cleanup efforts at DOE facilities, as well as improve the monitoring of contaminants in groundwater around existing and future radionuclide waste disposal and storage sites. These efforts also will assist the Department's research on using deep geological formations to store carbon dioxide taken from the atmosphere.

	FY 2007	FY 2008	FY 2009
▪ **General Purpose Equipment (GPE)**	**503**	**402**	**750**

GPE funding will increase to provide general purpose equipment for Pacific Northwest National Laboratory (PNNL) and Oak Ridge Institute for Science and Education (ORISE) such as information system computers and networks, and instrumentation that support multi-purpose research.

	FY 2007	FY 2008	FY 2009
▪ **General Plant Projects (GPP)**	**6,040**	**4,129**	**700**

GPP funding is continued for minor new construction, other capital alterations and additions, and for buildings and utility systems, such as replacing infrastructure in 30- to 40-year old buildings.

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

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 ORISE. The total estimated cost of each GPP project will not exceed $5,000,000. In FY 2009, funding is reduced as GPP for PNNL will now be funded as part of the laboratory's overhead and the funds previously allocated for PNNL GPP are transferred to the Science Laboratories Infrastructure program.

	FY 2007	FY 2008	FY 2009
▪ **Facility Operations**	**41,360**	**42,568**	**48,448**
• **EMSL Operating Expenses**	**35,532**	**36,122**	**36,335**

The William R. Wiley Environmental Molecular Sciences Laboratory (EMSL), a national scientific user facility located at the Pacific Northwest National Laboratory, provides integrated experimental and computational resources for discovery and technological innovation in the environmental molecular sciences to support the needs of DOE and the nation. Operating funds are used for: staff support for users; maintenance of instruments and buildings; utilities; environmental safety and health compliance activities; and communications. With over 55 leading-edge instruments and a supercomputer system, EMSL annually supports approximately 700 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 high performance computer; 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 June 2006, BER conducted a follow-on review of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) to validate the corrective actions taken in response to the management and operations findings of the BERAC and Office of Science/Office of Project Assessment reviews in May, 2005. These reviews validated the status of EMSL as a National Scientific User Facility. The June 2006 review committee found that actions taken in response to the May 2005 reviews were "timely, comprehensive, and on target" and that implementation of those actions was "effective, widely accepted, and appears to be on its way to completion".

In FY 2009, EMSL operations funding is held near level, supporting user facility operations and services to users.

	FY 2007	FY 2008	FY 2009
(dollars in thousands)			

	(estimated) FY 2007	FY 2008	FY 2009
Optimal hours	4,365	4,365	4,365
Scheduled hours	4,365	4,365	4,365
Operation Time	>98%	>98%	>98%
Users[a]	1,700	700	750

	FY 2007	FY 2008	FY 2009
• **Capital Equipment**	**5,828**	**6,446**	**10,113**

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 2009, a multi-year equipment refresh is initiated. Capital equipment funds will be used to enhance capabilities in electron paramagnetic resonance (EPR) spectroscopy (e.g., EPR for protein complex characterization), microbial dynamics and visualization capabilities (e.g., a 3D laser confocal microscope), surface dynamics (e.g., a spectroscopy and microscopy laser detection system, and a aerosol growth chamber interfaced with a Fourier Transform Infrared spectrometer), multiscale structure synthesis and characterization (e.g., a nano Secondary Ion Mass Spectrometer), and archive and data storage enhancements, as well as maintain existing user capabilities.

The Field Emission Transmission Electron Microscope (TEM) is funded in FY 2008 with a Total Estimated Cost of $4,500,000. This Major Item of Equipment will be delivered in FY 2009 and will enable EMSL users to image conversion reactions, including catalytic reactions, under actual reaction conditions at the atomic scale, and to thereby identify the specific reaction sites.

• **EMSL GPP**	**—**	**—**	**2,000**

In FY 2009, GPP is provided to initiate development and construction of an addition to EMSL. Approximately 4,000 square feet of specialized space will be added to house instrumentation for users to characterize and analyze radioactive materials and samples.

SBIR/STTR	**—**	**10,859**	**10,798**

In FY 2007, $8,574,000 and $1,029,000 were transferred to the SBIR and STTR programs, respectively. FY 2008 and FY 2009 amounts shown are the estimated requirements for continuation of the SBIR and STTR programs.

Total, Biological Research	**350,485**	**407,530**	**413,613**

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

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Life Sciences	
▪ **Molecular and Cellular Biology**	
• **Genomics: GTL**	
► **Genomics: GTL Foundational Research**	
Genomics: GTL Foundational Research increases to support technology development in imaging and in DNA sequence annotation in support of the bioenergy and carbon sequestration programs. SciDAC will also increase to support dynamic computational modeling of enzymes critical in bioenergy production.	+5,018
► **Genomics: GTL Bioethanol Research**	
GTL Bioethanol research increases to accelerate the identification of natural microbes and genetically engineered model microbes that demonstrate enhanced capability for commercial ethanol production.	+5,000
► **Low Dose Radiation Research**	
Low Dose Radiation Research increases to support comparative genomic studies to determine susceptibility of vulnerable populations to the effects of low dose radiation.	+3,025
Total, Molecular and Cellular Biology	**+13,043**
▪ **Human Genome**	
• **Tools for DNA Sequencing and Sequence Analysis**	
Production Genomics Facility funding is decreased to reallocate funding to Tools for DNA Sequencing and Sequence Analysis and to support other research priorities in BER.	-5,000
• **Tools for DNA Sequencing and Sequence Analysis**	
An increase to Tools for DNA Sequencing and Sequence Analysis will support the additional annotation and genome analysis requirements of the GTL Bioenergy Research Centers.	+2,267
Total, Human Genome	**-2,733**
▪ **Radiochemistry and Instrumentation**	
The decreased funding in FY2009 reflects the completion of awake animal imaging studies and pilot radiochemistry instrumentation projects initiated in FY2008.	-8,785
Total, Life Sciences	**+1,525**

	FY 2009 vs. FY 2008 ($000)
Environmental Remediation	
▪ **Environmental Remediation Sciences Research**	
Increased funding will enhance basic research on biogeochemical processes that control radionuclide and heavy metal transport in the subsurface environment.	+1,820
▪ **General Purpose Equipment (GPE)**	
General Purpose Equipment (GPE) increases to update network systems and associated instrumentation in support of multi-purpose research.	+348
▪ **General Plant Projects (GPP)**	
General Plant Projects (GPP) funding is reduced as GPP for PNNL will now be funded as part of the laboratory's overhead and the funds previously allocated for PNNL GPP are transferred to the Science Laboratories Infrastructure program.	-3,429
Total, Environmental Remediation Sciences Research	**-1,261**
▪ **Facility Operations**	
• **EMSL Operating Expenses**	
EMSL operations funding is held near level, maintaining operations at full capacity.	+213
• **Capital Equipment**	
EMSL capital equipment funding is provided to initiate a capital equipment refresh for EMSL that will provide users with leading-edge capabilities for atmospheric/aerosol chemistry research, biogeochemistry and subsurface science research, and interfacial science research.	+3,667
• **EMSL GPP**	
EMSL GPP is provided to initiate development and construction of an addition to EMSL. Approximately 4,000 square feet of specialized space will be added to house instrumentation for users to characterize and analyze radioactive materials and samples.	+2,000
Total, Facility Operations	**+5,880**
Total, Environmental Remediation	**+4,619**
SBIR/STTR	
▪ SBIR/STTR increases with increases in research funding.	-61
Total Funding Change, Biological Research	**+6,083**

Climate Change Research

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Climate Change Research			
Climate Forcing	76,148	77,961	81,173
Climate Change Modeling	25,375	31,017	45,387
Climate Change Response	24,235	19,380	19,380
Climate Change Mitigation	3,861	4,747	4,747
SBIR/STTR	—	3,762	4,240
Total, Climate Change Research	129,619	136,867	154,927

Description

BER priorities within the Climate Change Research subprogram are to develop the ability to predict climate on global and regional scales; to explore the impacts of excess atmospheric CO_2 on the Earth system; to develop strategies for its removal and sequestration from the atmosphere; and, provide the science to underpin the prediction of the impacts of climate change. These priorities will depend on the continued development of novel research tools and a close integration of experimental, observational, and computational research.

This subprogram's research is expected to reduce and resolve key uncertainties and provide the scientific foundation needed to predict, assess, and help mitigate greenhouse gas forcing of climate resulting from energy production and use. Climate forcing research leads to understanding and quantification of natural and human-induced forcing of the climate system and the processes that affect such forcing, including the role of clouds, aerosols, and carbon cycling. Climate change modeling research leads to the development, testing, and application of fully coupled climate and Earth system models needed to project the likely response of the climate system to natural and human-induced climate forcing. Climate change response research leads to the understanding and ability to predict the response of ecological and human systems to ongoing and projected future changes in climate and atmospheric composition associated with energy production. Climate change mitigation research leads to the development of strategies or technologies for modifying or managing terrestrial systems to enhance their sequestration capacity.

Periodic retrospective analysis is employed to evaluate program management processes, priorities, and outcomes. A second BERAC Committee of Visitors (COV) for the Climate Change Research subprogram was conducted in FY 2007 to provide outside expert validation of the program's merit-based review and funding decision processes that impact scientific quality, programmatic relevance, and performance. The full report and the BER response are at http://www.science.doe.gov/ober/berac.html. The next COV for the Climate Change Research subprogram will be in FY 2010. The BERAC is also tasked to conduct reviews of specific programs. The most recent was a review of the ARM Infrastructure in FY 2007. BERAC also reviewed the Integrated Assessment Research Program in early FY 2007.

FY 2007 Accomplishments

- **Data from Saharan Dust Storm Reveal Model Deficiencies:** The first scientific results from the deployment of the ARM Mobile Facility in Niamey, Niger, Africa show that in a dusty atmosphere, atmospheric radiation models generally underestimate the observed absorption of solar radiation. The mobile facility was deployed in Niamey, Niger to measure radiation, and cloud and aerosol properties during the monsoon and dry seasons. The first of several publications based on data obtained from the deployment focused on the impact on radiation of a large Saharan dust storm which raged across the North African desert in March 2006, the largest storm for the previous two years. Dust from Africa's Sahara desert—the largest source of dust on the planet—reaches halfway around the globe. Unfortunately, Africa is one of the least sampled climate regimes in the world, leaving scientists to wonder about its contribution to global climate. Saharan dust efficiently absorbs solar energy and transfers this heat to the atmosphere, which potentially alters the thermal properties of the atmosphere and affects the Earth's radiant energy budget.

- **Double Whammy to Arctic Climate:** The analysis of eight years data obtained from the Atmospheric Radiation Measurement program advanced instrumentation show that enhanced aerosol concentrations increase the amount of thermal energy emitted by many Arctic clouds to the surface, causing increased Arctic warming in addition to the greenhouse gas warming. The analysis also found that the magnitude of this increased warming is comparable to that of the surface warming effect by greenhouse gases, suggesting that aerosol indirect effect is significant to the Arctic energy balance. This study documents, for the first time, how the Arctic region's periodic influxes of anthropogenic aerosols is impacted by the industrial emissions from lower latitudes.
- **Importance of Anthropogenic Secondary Organic Aerosol**: About 90% of secondary organic aerosol (SOA) is currently believed to be due to biogenic volatile organic carbon compounds (VOCs). Anthropogenic VOCs have therefore not been included in most modeling studies that assess the relevance of SOA to climate forcing. However, a recent BER-funded study examining aerosol production in Mexico City indicates the presence of production pathways not accounted for in current atmospheric chemistry models, and that amounts of secondary organic aerosol produced from anthropogenic volatile organic carbon are as much as eight-fold greater than predicted by these models. Also contrary to current understanding, much of the excess secondary organic aerosol is formed from first-generation oxidation products. These findings demonstrate the importance of SOA as a major component of atmospheric aerosol whose influences on climate must be accurately represented in models.
- **Warming May Threaten Dryland Ecosystems:** A study of the response of grasses to an experimentally controlled year-round increase in ambient temperature of 2 degrees C (which climate models indicate might occur within 50 years), shows a 20% reduction in abundance of the dominant grass species relative to the controls exposed to ambient temperatures. More than one third of the United States is dryland, particularly in the West. Many dryland plants and animals live "on the edge," and warming has the potential to stress life in these already harsh environments. Unfortunately, little experimental data exist to determine how much of a threat warming is in dryland ecosystems. To obtain such data, DOE is sponsoring an experimental manipulation of temperature in a dryland ecosystem in eastern Utah. The decline in the abundance of the dominant grass species may have secondary ecological effects. This dominant grass species and other plants in dryland ecosystems protect soil from erosion, and they are a main food source for mice, rabbits, and other animals. Therefore, if future warming is detrimental to dryland plants, as indicated by these experiments, it could have undesirable secondary effects on the physical stability of dryland ecosystems as well as the health and success of animal species dependent on dryland plants for food and habitat.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Climate Forcing	**76,148**	**77,961**	**81,173**
▪ **Atmospheric Radiation Measurement (ARM) Research**	**14,794**	**14,765**	**14,765**

A major emphasis in the Climate Forcing area of the Climate Change Research subprogram is on understanding the radiation balance from the surface of the Earth to the top of the atmosphere and how this balance is affected by clouds, aerosols, and increases in the concentration of greenhouse gases in the atmosphere. There are two major emphases in the ARM Research. The first is to understand and relate observed solar radiative fluxes and radiances in the atmosphere to the temperature and composition of the atmosphere, specifically including water vapor and clouds, aerosols, and to surface properties, using a variety of ARM observations that span a wide range of climatologically relevant conditions. The second emphasis is to promote development and testing of cloud-aerosol-radiation parameterizations that can be used in General Circulation Models (GCMs) to accurately predict the radiative properties and radiative interactions involving water vapor and clouds within the atmosphere. An additional emphasis includes research to understand the processes in the terrestrial biosphere that affect the exchange of carbon dioxide between the terrestrial biosphere and atmosphere and to quantify their net effect on atmospheric concentrations of carbon dioxide so as to better understand how they might affect atmospheric concentrations and climate forcing in the future.

In FY 2009, ARM research will continue to focus on resolving the greatest scientific uncertainty in climate change prediction—the role of clouds and aerosols and their interactions with solar radiation. An important element of this research is on developing and improving parameterization schemes of processes that affect climate forcing so they can be included and tested in climate models. 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, GCMs. A major portion of this funding will specifically support research using new types of ARM data from, for example, field campaigns to develop and test parameterization schemes for processes that are tightly coupled as observed from the field campaigns (e.g., land and ocean surface processes and their interaction with overlying boundary layer and clouds) and incorporate them in GCMs to test and compare their performance in improving climate simulations.

ARM research supports individual investigators at universities and research teams at DOE laboratories involved in studies of cloud physics and dynamics, 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. Focus groups of scientists from many of the DOE laboratories will contribute to comprehensive and cohesive research efforts as opposed to individual research during the past years. Networking also occurs with the federal scientists at NASA, NOAA, and DOD. To facilitate the knowledge transfer from the ARM program to the premier modeling centers and academic institutes, the ARM science program also supports ARM site scientists and scientific "Fellows" at the National Center for Atmospheric Research, Geophysical Fluid Dynamics Laboratory, and the European Center for

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

Medium-Range Weather Forecasting. In addition, the model parameterization test bed implemented at Lawrence Livermore National Laboratory will be continued to enable the developing and testing of better parameterization schemes and submodels by rapidly incorporating ARM measurements into the GCMs.

▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**	**34,783**	**35,251**	**37,853**

In February 2007, BER conducted a review of the ARM Climate Research Facility (ACRF) to determine the scientific and cost effectiveness of the facility operation. The review found that the ACRF provides uniquely valuable resources for the global climate research community. The review panel found that the ACRF has effectively implemented numerous cost reduction measures while simultaneously increasing the number of products delivered to the user community.

In FY 2009, the ARM infrastructure activity will continue to support and upgrade the operation of the ARM Climate Research Facility (ACRF). The ACRF consists of three stationary facilities, an ARM Mobile Facility (AMF), and the ARM Aerial Vehicles Program (AAVP). The stationary sites provide scientific testbeds in three different climatic regions (mid-latitude, polar, and tropical); the operating paradigm of continuous measurement of atmospheric and surface properties at long-term sites is well suited to climate studies. The AMF provides a capability to address high priority scientific questions in regions other than the stationary sites. The AAVP provides a capability to obtain *in situ* cloud and radiation measurements that complement the ground-based measurements.

The ACRF provides the infrastructure needed for studies investigating atmospheric processes and for climate model development and evaluation. As a scientific user facility, ACRF supports hundreds of scientists from universities and government laboratories. Support for the science community includes access to data from the ARM archive and infrastructure needed to conduct experiments at the facilities, both ground and aerial. Selection of proposed experiments for implementation is based on a solicitation for proposals and a competitive merit review. Ranging from two weeks to a year, the campaigns bring together teams of national and international scientists to coordinate measurements with airborne and satellite observations to measure particular processes and their effects on radiation around one of the facilities. Both NASA and DOD, for example, use the ACRF facilities to “ground truth” measurements made with some of their satellite-based instruments. The CCRI ARM Infrastructure activity 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 budget increase will be used to begin developing a second ARM mobile facility for deployment in FY 2010. The primary criterion for deployment of the mobile facilities is to provide needed measurements to address specific modeling needs that cannot be provided by measurements from the stationary ARM facilities. The deployment location for the ARM mobile facilities and the scientific focus and location of ACRF campaigns in FY 2009 have not yet been determined, but a decision is expected following the review of proposals that were solicited from the research community. In FY 2009 ACRF will continue to add new instrumentation for characterizing the 3D structure of clouds.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

	(estimated)		
	FY 2007	FY 2008	FY 2009
Optimal hours	7,884	7,884	7,884
Scheduled hours	7,884	7,884	7,884
Operation Time	>98%	>98%	>98%
Users[a]	850	900	900

	FY 2007	FY 2008	FY 2009
▪ **Atmospheric Science**	**12,241**	**12,633**	**13,051**

The Atmospheric Science Program (ASP) is focused on the radiative effects of atmospheric aerosols, the greatest source of uncertainty in global radiative forcing of climate change over the last century. To enable more reliable and accurate simulations of direct and indirect aerosol climate forcing, the program conducts research on the atmospheric processes that control the formation, transport, transformations, and removal of atmospheric aerosols as these affect their distribution, radiative, and cloud nucleating properties.

In FY 2009, ASP will continue its mission to characterize aerosol physical, chemical, and optical properties and their effects on the Earth's energy balance. These studies include laboratory and field research on key processes individually and as encountered in "real world" environments. Acquired data are used to develop and test predictive parameterization schemes or models for aerosol properties and their effect on radiative transfer in the atmosphere. Field and laboratory observations are also used to interpret and extend the results of process model simulations. Current priority atmospheric processes under study include transformations and properties of carbonaceous aerosols, especially secondary organic aerosols, which are poorly predicted by current atmospheric models. Also important are processes controlling new particle formation and growth, as well as the properties that affect their activation as droplet and crystal nuclei.

In early FY 2009 the ASP will participate in a major collaborative interagency field campaign aimed at measuring interactions of aerosols with clouds over the Southern Pacific Ocean near Chile, a region that is impacted both by pristine and polluted air masses. One specific objective of ASP activity is to test new process models of drizzle formation that show promise for inclusion into global climate models.

	FY 2007	FY 2008	FY 2009
▪ **Terrestrial Carbon Processes**	**12,326**	**13,439**	**13,631**

In FY 2009, BER will continue support of AmeriFlux, a network of research sites where the net exchange of carbon dioxide, energy, and water between the atmosphere and major terrestrial ecosystems in North America is continuously measured. Approximately 20 of the sites are funded by BER at an average of $200,000 each, along with quality assurance of the measurements and data, and data archiving to make it available to the broader scientific community. There are approximately 70 additional sites in the AmeriFlux network that are funded by other agencies (NASA, NOAA, United States Geological Service (USGS), Forest Service, and Agriculture Research Service). The AmeriFlux measurements are linked to field measurement campaigns across major regions of North

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

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

America that are designed to test how well point measurements of fluxes represent fluxes observed over larger areas within the same region and allow the estimate of carbon sources and sinks on a regional and eventually a national or continental basis.

In FY 2009, the AmeriFlux Network research sites will provide extensive measurements of terrestrial carbon sink properties, including biological and soil carbon processes. This research is important for evaluating what happens to carbon dioxide emissions from combustion of fossil fuels, and provides scientific information needed for prognostic modeling of the rate of atmospheric carbon dioxide increase, which is a key forcing factor of climate. Improved understanding of the terrestrial carbon cycle is also an integral component of the North American Carbon Program (NACP), which is employing two independent analytical methods to build confidence in estimates of the North American terrestrial carbon sink. Using common protocols across the Network, a comprehensive and coherent suite of measurements will be produced that will include radiation and micrometeorology properties, carbon dioxide and water flux, and physiological/biological/soil carbon processes that affect the net exchange of carbon dioxide between terrestrial ecosystems and the atmosphere. A key measurement will be the direct observation of net ecosystem exchange (NEE) of carbon dioxide that represents the quantity of carbon that is gained or lost from an ecosystem. Linking these comprehensive observations with forest and crop inventory data (from USDA/Forest Service) and with remote sensing observations (from NASA), the suite of observations is integrated using terrestrial ecosystem and landscape models to produce a “bottom-up” calculation of distributed carbon sinks across North America. This “bottom-up” estimate will be compared with a “top-down” calculation of the carbon sink that is based on atmospheric carbon dioxide measurements at continental boundaries and inverse modeling methods. While the “top-down” analysis will be performed by other Agencies of the NACP (i.e., NOAA, NASA, and NSF), the AmeriFlux Network will provide high precision atmospheric carbon dioxide measurements that are essential for constraining the “top-down” calculations. The pivotal AmeriFlux observations of carbon dioxide fluxes and factors that control them and the carbon cycle modeling will contribute significantly to the highly coordinated inter-agency NACP research on the magnitude and longevity of North American carbon sinks, which is a top priority of the U.S. Climate Change Science Program. The AmeriFlux research together with related observations and modeling approaches of other Agencies will provide the Nation with the needed quantification of North American terrestrial carbon sinks, with unique diagnostic tools and prognostic models for predicting future atmospheric carbon dioxide increase that will be on par with analytical capabilities of other areas of the globe (e.g., the European Union).

▪ **Ocean Sciences**	**136**	**—**	**—**

Ocean sciences research was concluded in FY 2007.

▪ **Information and Integration**	**1,868**	**1,873**	**1,873**

The Information and Integration element of Climate Forcing research will continue to store, evaluate, quality assure, and disseminate a broad range of climate change related data, especially data on atmospheric concentrations and industrial emissions of greenhouse gases, greenhouse gas fluxes from terrestrial systems, ocean CO_2 data, and air quality data. This is accomplished by supporting the Carbon Dioxide Information and Analysis Center (CDIAC). CDIAC's data holdings include records of the concentrations of carbon dioxide and other radiatively active gases in the atmosphere; the role of the terrestrial biosphere and the oceans in the biogeochemical cycles of greenhouse gases; emissions of carbon dioxide to the atmosphere; long-term climate trends; the effects of elevated carbon dioxide on vegetation; and the vulnerability of coastal areas to rising sea level. These data are used by the climate change research community for assessing changes in climate forcing due to increasing concentrations and emissions of greenhouse gases. These data are evaluated and quality assured before being disseminated. CDIAC will continue to archive, manage, and disseminate ocean carbon data. CDIAC is recognized by the World Meteorological Organization 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. CDIAC serves as the Quality Systems Science Center for the tri-lateral (U.S., Mexico, and Canada) NARSTO (formerly known as the North American Strategy for Tropospheric Ozone), 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. In FY 2009 CDIAC will release a database of fossil-fuel emissions data developed for use in coupled climate-carbon cycle models and Earth system models. In FY 2009, CDIAC will also produce the 2008 global fossil-fuel CO_2 emission estimates.

	FY 2007	FY 2008	FY 2009
Climate Change Modeling	**25,375**	**31,017**	**45,387**

During the past decade, considerable advances have been made in the understanding, detection and attribution of past climate change, and in projecting future changes in climate using state-of-the-art climate models. However, uncertainties due to climate forcings and feedbacks have not yet been resolved, e.g., current state-of-the-science coupled atmosphere-ocean-land-sea ice models that simulate climate variability and change over decadal to centennial time scales still have systematic precipitation biases. Improvements are needed before models can simulate regional climate variability and change with greater fidelity.

In FY 2009 BER is requesting enhanced funding to directly address these uncertainties. This effort will be closely coordinated with BER's SciDAC for Climate Change Research activities and will enhance BER's partnerships with the Advanced Scientific Computing Research program. The focus will be on incorporation and testing of various aerosol schemes, convection schemes, ice sheets, and land surface schemes in the coupled models, and evaluation using innovative metrics that span a variety of climate time scales. Specifically:

- Testing of newly developed convection schemes, cloud parameterization schemes, global cloud resolving models against observations. The emphasis of this research will be on testing cloud-aerosol-radiation parameterization schemes in Global Circulation Models (GCM).
- Characterizing aerosol-climate interactions. The greatest uncertainty in climate forcing continues to be the role of clouds and aerosols. An important element of this work will be on testing and improving aerosol parameterization schemes in atmospheric GCMs. New types of ARM data, e.g. from field campaigns that aim at understanding atmospheric properties and processes, will be brought to bear to support this research.
- Exploring Decadal Predictability of the Climate System. Currently climate models are run under emission scenarios without initializing using observations. The new effort will aim at understanding

climate change prediction using improved initialization of the ocean and other components.

- Understanding Cryospheric Processes and their role in the Climate System. Arctic sea ice declined rapidly to unprecedented low extents in the summer of 2007 raising concern that the Arctic may be on the verge of a fundamental transition toward a seasonal ice cover. Models significantly under represent the observed trend. The reasons for this under representation remain to be fully resolved; understanding cryospheric processes requires a concerted enhanced research. Similarly the role of land-ice in the climate system will be explored.
- Understanding Climate Extremes in a Changing Climate: Climate extremes have large impacts on society. The statistics of climate extremes (temperature, precipitation) will change as climate changes. Understanding and attributing climate extremes will be a new area of study.
- Research to develop Metrics for evaluation of climate models. BER has lead the community in model diagnoses and intercomparison. It is becoming increasingly apparent that there is no single set of universal metrics for climate model evaluation and diagnostics, rather it depends on the scientific question being addressed. For each of the themes being studied (decadal prediction, cryospheric processes, climate extremes) there will be a need to understand why various climate models are giving differing answers. This would lead to a set of metrics relevant to addressing the specific issue. BER will take a proactive role in developing these metrics and diagnostic tools.
- BER will develop new metrics for ocean model evaluation and diagnostics. The new studies of decadal predictability, cryosphere, and climate extremes will also require associated metrics for model evaluation. BER will develop and apply these for the two themes mentioned above.
- Research to develop and employ Enabling Technologies for climate model simulation dissemination: Climate change information is being increasingly sought for impact studies, national and international assessments. The activity is at the interface of process research and the global climate modeling, and is expected to accelerate process representation in coupled earth system models for climate change projections. As part of this new thrust, an effort will also be initiated to strengthen the connections between the integrated assessment and the climate modeling research communities with the objective to bring to bear improved understanding of the human-earth systems dynamics for comprehensive, realistic projections of timing, scale, and geographic distribution of emissions trajectories and other critical parameters of interest. The DOE leadership class computational facilities now provides computing resources for models to be run at resolutions at which complex issues of data archival, management, dissemination need to be addressed. BER will develop such tools and capability.

BER will continue projects initiated in FY 2008 on the topic of abrupt climate change will be at a level of approximately $2,600,000. BER research will undertake the following: understanding the thresholds and nonlinearities in the climate system with a focus on mechanisms of abrupt climate change, incorporating mechanisms into coupled climate models, and testing the models vis-à-vis records of past abrupt climate change. DOE’s focus on Abrupt Climate Change Modeling is attribution of past abrupt climate change, and potential future abrupt climate change based on climate projections using a model that includes different mechanisms that have been hypothesized as causes of abrupt climatic change.

BER will also continue to support and coordinate model-data intercomparisons, the development and improvement of metrics and diagnostic tools for evaluating model performance, and the maintenance of

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

test beds for evaluating model parameterizations. The effort will move beyond the traditional testing of atmospheric models to include testing and evaluation of high-resolution ocean models, e.g., eddy-permitting and eddy-resolving simulations.

BER's SciDAC for Climate Change Research ($7,776,000) will continue partnerships with the Advanced Scientific Computing Research program. This will include work towards the creation of a first-generation Earth System model based on the Community Climate System Model that treats the coupling between the physical, chemical, and biogeochemical processes in the climate system. The model will include comprehensive treatments of the processes governing well-mixed greenhouse gases, natural and anthropogenic aerosols, the aerosol indirect effect and troposhpheric ozone for climate change studies. Research will develop and test a global cloud resolving model using a geodesic grid, with grid-cell spacing of approximately 3 km, capable of simulating the circulation associated with large convective clouds.

The SciDAC university grants initiated in FY 2007 will continue to work on emerging topics on climate change science, e.g., tropical cyclone activity in future climate regimes, evaluation of the upward branch of the deep conveyor belt in ocean models, climate change in the Arctic, annual-cycle El Niño/Southern Oscillations interactions, carbon data assimilation data sets using improved techniques, investigation of regional climate variability and change in the Atlantic Sector, and climate change projections in the Asian monsoon region. The program will continue work on development of an atmospheric model with self-adapting grid and physics, global cloud resolving modeling, new grid and discretization technologies for ocean and ice simulations, a subgrid scaling framework to improve land simulation, and subgrid scale mixing in atmospheric models.

Climate Change Response	**24,235**	**19,380**	**19,380**
▪ **Ecosystem Function and Response**	**12,887**	**13,182**	**13,182**

The goal of the Ecosystem Function and Response research activity is to understand the potential effects of climatic change anticipated during the coming 50-100 years on the health of important terrestrial ecosystems in the United States. While ecosystem models can provide hypothetical projections of ecological responses to climatic change, present models are seriously limited by lack of relevant experimental data. To address this problem, BER sponsors experimental studies of the potential effects of warming, and changes in precipitation, on multiple terrestrial ecosystems. The new scientific data and understanding obtained by this research will facilitate informed decision making about the means of producing the energy needed by society. It will do this by defining relationships between climatic changes that might be caused by energy production and the potential effects of those changes on the health of terrestrial ecosystems, and the organisms that they contain.

The primary focus in FY 2009 will be experimental studies of the potential effects of warming on the abundance and geographic distribution of plant and animal species in several ecosystem types. The experiments will be conducted to fill specific critical knowledge gaps. In particular, experiments will determine linkages between warming and the possibility of species migrations, the expansion of species into areas that are presently too cool for their success, and the decline of species or ecosystems presently at the warm edge of their ranges. Field experiments will be conducted in high-elevation forests and meadows associated with the alpine tree line, the transition zone (ecotone) between temperate and boreal forests, and western shrubland. Field experiments in other ecosystems will be initiated in FY 2009 based on results of a competition planned for in FY 2008. In addition to field experiments, laboratory experiments will determine relationships between warming and the success of plants and animals in model ecosystems. Laboratory studies will focus on key testable hypotheses about ecological effects of warming.

The secondary focus in FY 2009 will be experimental studies of the potential ecological effects of changes in the annual amount, or seasonal timing, of precipitation. Climate models project reductions in precipitation in the southwestern United States, which has the potential to affect many southwestern ecosystems. Unique field experiments will document effects of experimentally altered rainfall on southwestern woodlands (including the geographically extensive pinyon-juniper ecosystem), forests, grasslands, and shrublands.

In FY 2009, the activity will continue to provide the core support for the operation of the world's largest long-term field study of the potential effects of changes in atmospheric composition caused by energy production on a terrestrial ecosystem (approximately $1,500,000). That experiment (in central Wisconsin) is enriching the atmosphere within forest communities with carbon dioxide and ozone concentrations that are anticipated to occur within 50 years. The experiment is documenting direct and indirect effects of elevated carbon dioxide and/or ozone on three tree species, soil microorganisms, and pests that feed on trees. The experiment is used by multiple research groups from universities and federal agencies in the United States and from other nations.

	FY 2007	FY 2008	FY 2009
▪ **Free Air Carbon Dioxide Enrichment (FACE) Facility**	**4,977**	**—**	**—**

In FY 2008, support for the conduct of FACE experiments was discontinued as user facility activity. Instead, research experiments at the existing FACE sites in Wisconsin, Nevada, North Carolina, and Tennessee continue. Support for one of the FACE sites is provided by the Ecosystem Function and Response activity and three are supported by the Terrestrial Carbon Processes activity. Rather than as a user facility, the FACE activity is best characterized as field experiments in which multiple investigators jointly participate as collaborators to understand the direct effect of elevated carbon dioxide and other trace gases on terrestrial ecosystems.

	FY 2007	FY 2008	FY 2009
▪ **Integrated Assessment**	**4,950**	**4,772**	**4,772**

BER's Integrated Assessment Research (IA) supports underlying research and development of the basic methods and models for estimating costs and benefits of global climate change and possible actions to mitigate such change. Understanding the underlying and complex human-earth systems dynamics are a priority for IA research. Similarly, understanding the role of present and possible future energy technologies remains a central focus of the research, leading to improved understanding of potential emissions trajectories and the environmental costs and benefits of stabilization options.

In 2009, the program will continue to advance research on the integrated drivers of climate change. However, and consistent with recommendations by the Biological and Environmental Research Advisory Committee, the independent advisory group for BER, the activity will undergo a transformation and will shift considerable attention to the challenge of representing climate change impacts and adaptations within IA models. This shift represents a significant new direction for IA. It is, however, a necessary change if BER is to provide balanced scientific perspectives and capabilities

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

that address both drivers and responses, or more specifically, costs and benefits, within integrated assessment frameworks. Development of non-monetary valuation and visualization methods and tools will be an important dimension of this new work. Additionally, BER will explore the application of more advanced computational platforms reflecting the need for tighter coupling between what are presently reduced-form IA models and the rich detail and reduced uncertainty of underlying biogeophysical models. The latter typically run on supercomputers. BER also recognizes that even reduced-form and meso-scale models of the combined human-earth systems interactions are pressing the limits of computer workstations. The program will strengthen its role in scenario analysis through supporting the climate science community with feedback on the scale, timing, and geographic distribution of parameters of interest for the development and calibration of Earth Systems Models.

	FY 2007	FY 2008	FY 2009
▪ **Education**	**1,421**	**1,426**	**1,426**

BER's Global Change Education Program will continue to support both undergraduate and graduate studies in FY 2009 through the DOE Summer Undergraduate Research Experience (SURE) and the DOE Graduate Research Environmental Fellowships (GREF). The GREF and the SURE provide a total of 45 students with support to conduct research that is of interest to them and relevant to DOE's climate change research. Their research is conducted under a mentor of their choice at either a university or a DOE laboratory. Funding for GREF and SURE only supports the students, not the mentor under which they each choose to work. The SURE continues to be a magnet for highly qualified undergraduates, most of who go to graduate school to study in fields directly related to what they did under SURE. Similarly students in the GREF program have received graduate degrees and many have stayed in the field and initiated their own research related to climate change.

	FY 2007	FY 2008	FY 2009
Climate Change Mitigation	**3,861**	**4,747**	**4,747**

In FY 2009, BER's carbon sequestration research, part of BER's support to the Climate Change Technology Program, will continue to focus only on terrestrial carbon sequestration. Research will continue on studies to enhance long-term sequestration processes and the stability of stored carbon in terrestrial vegetation and soils. In FY 2009, the research will be organized around switchgrass (*Panicum virgatum*) that will be employed in DOE's "ethanol from cellulose" research. Preliminary studies with switchgrass, a native, warm-season perennial grass with C-4 carbon metabolism, suggest that switchgrass develops an extensive rooting system that could possibly be managed for enhanced soil carbon sequestration. The research will determine if "double dividends" can be achieved from switchgrass systems that provide cellulose for ethanol production and simultaneously enhance soil carbon sequestration. The overall goal is to understand and quantify physical, chemical, and biological controls over soil carbon sequestration using switchgrass as the test bed. The research will be carried out through field experiments with switchgrass at Milan, Tennessee, and the Fermi laboratory site at Batavia, Illinois, which will produce results on below-ground carbon transformations that involve biological guilds of roots, rhizosphere and microbial communities. The role of microaggregates and other soil properties in stabilizing and protecting carbon complexed with soil minerals will also be investigated. Data from the field experiments will be provided for mechanistic and prognostic modeling soil carbon sequestration of the switchgrass system.

	FY 2007	FY 2008	FY 2009
SBIR/STTR	**—**	**3,762**	**4,240**

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
In FY 2007, $3,311,000 and $397,000 were transferred to the SBIR and STTR programs, respectively. FY 2008 and FY 2009 amounts shown are the estimated requirements for continuation of the SBIR and STTR programs.			
Total, Climate Change Research	**129,619**	**136,867**	**154,927**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Climate Forcing	
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**	
The ARM infrastructure increases to begin development of a second mobile ARM Climate Research Facility.	+2,602
▪ **Atmospheric Science**	
Atmospheric Science research increases to support additional research on aerosol properties and processes, including their transport and transformations that affect their radiative properties in the atmosphere.	+418
▪ **Terrestrial Carbon Processes**	
Terrestrial Carbon Processes is held near the FY 2008 level.	+192
Total, Climate Forcing	**+3,212**
Climate Change Modeling	
Climate Modeling increases to exploit the Department's leadership class computing facilities to determine the effect of both resolution and improved model physics, including ice sheets, in a fully coupled climate model for use in both on simulating historic climate at decade and longer time scales and regional to global spatial scales and projecting future potential climate change at regional to global scales in response to different plausible scenarios of natural and/or human-induced forcing.	+14,370
SBIR/STTR	
SBIR/STTR increases due to research program increases.	+478
Total Funding Change, Climate Change Research	**+18,060**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
General Plant Projects	6,040	4,129	2,700
Capital Equipment	12,483	14,998	28,777
Total, Capital Operating Expenses	18,523	19,127	31,477

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

(dollars in thousands)

	Total Project Cost (TPC)	Other Project Costs (OPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Completion Date
EMSL Field Emission Transmission Electron Microscope, PNNL	4,500	—	4,500	—	—	4,500	—	FY 2008

High Energy Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
High Energy Physics					
Proton Accelerator-Based Physics	343,633	376,702	-7,877[abc]	368,825	419,577
Electron Accelerator-Based Physics	101,284	78,763	-13,169[ab]	65,594	48,772
Non-Accelerator Physics	60,655	61,800	+12,399[ab]	74,199	86,482
Theoretical Physics	59,955	56,909	+3,325[ab]	60,234	63,036
Advanced Technology R&D	166,907	120,464	+15[ab]	120,479	187,093
Total, High Energy Physics	732,434[d]	694,638	-5,307[a]	689,331	804,960
Stanford Linear Accelerator Center (SLAC) Linac Operations (non-add)[e]	(51,300)	(20,000)	(-183)[a]	(19,817)	(—)
High Energy Physics, excluding SLAC Linac Operations (non-add)[e]	(681,134)	(674,638)	(-5,124)[a]	(669,514)	(804,960)

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"

Mission

The mission of the High Energy Physics (HEP) program is to understand how our universe works at its most fundamental level. We do this by discovering the most elementary constituents of matter and energy, probing the interactions between them, and exploring the basic nature of space and time itself. These fundamental ideas are the foundation of our understanding of the universe, its origins, and its destiny. To enable these discoveries, HEP supports theoretical and experimental research in both elementary particle physics and fundamental accelerator science and other supporting technology. HEP underpins and advances the Department of Energy (DOE) missions and objectives through this research,

[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008, as follows: Proton Accelerator-Based Physics ($-3,428,000), Electron Accelerator-Based Physics ($-717,000); Non-Accelerator Physics ($-562,000); Theoretical Physics ($-518,000); and Advanced Technology R&D ($-1,096,000).
[b] Reflects a reallocation of funding in accordance with the Energy and Water Development Conference Report, as follows: Proton Accelerator-Based Physics ($-5,463,000), Electron Accelerator-Based Physics ($-12,452,000); Non-Accelerator Physics ($+12,961,000); Theoretical Physics ($+3,843,000); and Advanced Technology R&D ($+1,111,000).
[c] Reflects an approved reprogramming from prior year balances of $1,014,000.
[d] Total is reduced by $19,352,000: $17,279,000 of which was transferred to the Small Business Innovative Research (SBIR) program and $2,073,000 of which was transferred to the Small Business Technology Transfer (STTR) program.
[e] The SLAC linear accelerator (linac) supports operations of the B-factory (funded by HEP) and will also support operations of the Linac Coherent Light Source (currently under construction and funded by Basic Energy Sciences (BES)). With the completion of B-factory operations in FY 2008, SC has been transitioning funding of the SLAC linac from HEP to BES, with FY 2008 representing the third and final year of joint funding with BES. HEP totals without SLAC linac funding are presented to display program growth exclusive of this functional transfer.

and by the development of key technologies and trained manpower needed to work at the cutting edge of science.

Description

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.

Nevertheless, the Standard Model is understood to be incomplete. Startling new data have revealed that only about 5% of the universe is made of the normal, visible matter described by the Standard Model. The other 95% of the universe consists of matter and energy whose fundamental nature is a mystery. The Standard Model's orderly and elegant view of the universe must somehow be incorporated into a broader and deeper theory where these new phenomena take their natural places. The new phenomena beyond it should appear at the energy scale accessed by new facilities.

A revolution in particle physics, and in our understanding of the universe in which we live, is coming.

Questions and the Quest for Answers

A world-wide program of particle physics research is underway to explore the new scientific landscape. The long-term plan for the U.S. HEP program prepared by the National Academy of Sciences ("Revealing the Hidden Nature of Space and Time") recommends the thoughtful pursuit of a high-risk, high-reward strategy to explore the energy frontier, called the "Terascale". At Terascale (meaning 10^{12} electron volts, or TeV for short) energies, questions in cosmology and particle physics are closely connected: the history, nature, and ultimate fate of the universe depend intimately on elementary particles and their interactions.

Here are some of the key questions the HEP program is addressing, and how we are seeking the answers:

- Are there undiscovered principles of nature: new symmetries, new physical laws?

  The laws of quantum physics that describe elementary particles and forces are based on underlying symmetries of nature. Some of these prevail only at very high particle energies. One possible and well motivated new symmetry, called supersymmetry, relates particles and forces. It predicts a "superpartner" for every particle we know, the lightest of which should be produced and observed at accelerators operating at the Terascale.

- How can we solve the mystery of dark energy?

  The "dark energy" that permeates empty space and accelerates the expansion of the universe must have a quantum explanation, in the same way that the quantum theory of light and the atom explained mysterious atomic spectra. More precise experimental data on dark energy, along with new theoretical ideas, are necessary to make progress on this fundamental problem.

- Are there extra dimensions of space?

  “String theory” is an attempt to unify physics by explaining particles and forces as the vibrations of tiny strings. String theory requires supersymmetry and seven extra dimensions of space. Evidence of such extra dimensions which support string theory could be seen at Terascale accelerators.

- Do all the forces become one?

  All the basic forces in the universe could be various manifestations of a single unified force. Unification was Einstein’s great, unrealized dream, and recent advances in string theory give hope of achieving it. The discovery of superpartners or extra dimensions at Terascale accelerators would lend strong support to current ideas about unification.

- Why are there so many kinds of particles?

  Three different “families” of quarks and leptons have been discovered. Moreover, quarks and leptons have widely different masses and force couplings. These variations suggest there may be undiscovered simplifying principles that connect quarks and leptons, just as the discovery of quarks simplified the “zoo” of composite particle states discovered in the 1960’s. Detailed studies at accelerators will provide the clearest insights into this complex puzzle.

- What is dark matter? How can we make it in the laboratory?

  Most of the matter in the universe is invisible and interacts very rarely with normal matter. This “dark matter” is thought to consist of exotic particles that have survived since the Big Bang. They may be reproduced and studied at Terascale accelerators, or detected in cosmic rays by using ultra-sensitive detectors.

- What are neutrinos telling us?

  Of all the known particles, neutrinos are perhaps the most mysterious. They played an essential role in the evolution of the universe, and flood otherwise empty space, but most pass right through the Earth undeflected and void of interaction. Their tiny masses may imply new physics and provide important clues to the unification of forces. Neutrinos are produced by cosmic rays, where they can be studied, as well as with experiments at accelerators and nuclear reactors.

- How did the universe come to be?

  The Big Bang (our universe) began with a singular disturbance of space-time, followed by a burst of inflationary expansion of space itself. The universe then expanded more slowly and cooled, allowing the formation of stars, galaxies, and ultimately life. Understanding the very early evolution of the universe will require a breakthrough in physics: the theoretical reconciliation of quantum mechanics with gravity.

- What happened to the antimatter?

  By all observation the universe appears to contain very little antimatter, although the Big Bang should have produced equal amounts of matter and antimatter, a fact that is supported by high-energy collisions in the laboratory. Precise accelerator-based measurements of the subtle asymmetries present in the weak nuclear interaction may shed light on how this asymmetry arose.

All these questions are addressed at some level by the existing and planned HEP program described in this budget request. Theoretical research, development of new and enabling technologies, 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.

While exploration of the scientific opportunities of the energy frontier at the Terascale is identified as a priority, it is also critical to maintain a diverse portfolio of activities in particle physics, from theory to accelerator R&D to construction and support of new experimental facilities. A central challenge for the U.S. and international high energy physics community is defining and executing a robust and balanced scientific program that includes provision for a new research collider at the energy frontier. The International Linear Collider (ILC), which is widely viewed as that collider, is a complex, technologically challenging multi-billion dollar investment requiring international commitments and years of R&D and design work before it might become a reality. The physics case and some design parameters for the ILC depend on physics results from the Large Hadron Collider (LHC) at CERN that will probably not be available for at least a few years. Recognizing the strong endorsement of the ILC from the U.S. and international HEP communities and from the National Academy of Sciences, we support a U.S. role in the global ILC R&D effort, in the context of an appropriately balanced HEP program that will enable the U.S. to play a leadership role in targeted research areas, both in the LHC era and whatever comes next.

In order to maintain this balance, the U.S. involvement in the global ILC R&D effort is focused on areas where the U.S. is the acknowledged leader. This becomes part of an overall strategy for accelerator R&D that has both near- and long-term components, and it provides the U.S. options over the next decade to exploit the most scientifically compelling accelerator facilities. With the Fermi National Accelerator Laboratory (Fermilab) Tevatron Collider nearing the end of its scientific program, investments must be made to develop the capabilities and infrastructure for a next generation of experimental tools.

The HEP program supported by this request allows the U.S. to continue its leadership at the energy frontier with the Tevatron as long as possible and play a strong role in the LHC program; to pursue an internationally coordinated, staged program in neutrino physics that will establish a U.S. leadership role in this area in the next decade; and to address compelling non-accelerator scientific opportunities and in particular, to expand the program in particle astrophysics.

- FY 2009 funding is provided to operate the Tevatron for its planned 42 week (5,040 hours) schedule. The luminosity improvements of the Tevatron Collider have been successfully carried out, enabling the Tevatron to open a window of discovery for the long-sought Higgs particle in advance of significant data from the LHC. The possibility of Tevatron operations for an addition year in FY 2010 will be revisited in FY 2008 when more Tevatron data have been analyzed and the LHC turn-on schedule is better understood.
- As the LHC accelerator nears its turn-on date in 2008, U.S. activities related to fabrication of detector components are complete and new activities related to commissioning and pre-operations of these detectors, along with software and computing activities needed to analyze the data, are being ramped-up. Support of an effective role for U.S. research groups in LHC discoveries will continue to be a high priority of the HEP program. R&D to explore possible options for upgrades to the LHC accelerator and detectors is supported.
- Increased funding is provided in FY 2009 for targeted areas in accelerator R&D, in accordance with recommendations from High-Energy Physics Advisory Panel (HEPAP) and external program reviews, to begin implementation of a strategic plan for technology R&D in the HEP program. These increases are directed at four distinct areas: (1) short-term R&D focused on addressing the issues associated with the development of a high intensity proton source for an enhanced neutrino program at Fermilab; (2) mid-term R&D directed at developing superconducting radiofrequency technologies

and infrastructure for the HEP program and the U.S.; (3) mid-term R&D directed towards the proposed ILC that is focused on areas where the U.S. is acknowledged expert, and that is internationally coordinated; and (4) long-term R&D directed at advanced accelerator technologies with the promise of transformational changes. Overall funding for technology R&D activities is actually below the FY 2007 level-of-effort but is better aligned with programmatic priorities.

- Funding is provided for the Dark Energy Survey (DES), Reactor Neutrino Detector (Daya Bay) and Cold Dark Matter Search (CDMS) Major Items of Equipment (MIEs) and for R&D for a Joint Dark Energy Mission (JDEM). Each of these has the potential for shedding new information and insight on the mysteries of dark matter and energy.

Strategic and GPRA Unit Program Goals

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

Strategic Theme 3, Scientific Discovery & Innovation

- Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.
- Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory infrastructure required for U.S. scientific primacy.

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

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

Contribution to GPRA Unit Program Goal 3.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space

The HEP program contributes to this goal by advancing our understanding of the basic constituents of matter and the forces between them, deeper symmetries in the laws of nature at high energies, and mysterious phenomena that pervade the universe, such as dark energy and dark matter. HEP uses particle accelerators and very sensitive detectors to study fundamental particle interactions at the highest possible energies. Because particle physics is deeply connected to the origin and evolution of the universe itself, the HEP program also supports non-accelerator studies of cosmic particles and phenomena including experiments conducted deep underground, on mountains, or in space. This research at the frontier of science may discover new particles, forces, or undiscovered dimensions of space and time; explain how matter came to have mass; and reveal the underlying nature of the universe. In particular, the HEP program seeks to identify the mysterious dark matter that holds galaxies together and the even more mysterious dark energy that is stretching space apart; explain why there is any matter in the universe at all; and show how the tiniest constituents of the universe play a leading role in shaping its birth, growth, and ultimate fate. Our goals in FY 2009 address all of these questions.

The FY 2009 budget request places high priority on operations, upgrades, and infrastructure for the two major HEP user facilities: the Tevatron Collider and Neutrinos at the Main Injector (NuMI) at Fermilab, to produce maximum scientific data to address these fundamental questions. FY 2008 is the final year of operations for the B-factory at the Stanford Linear Accelerator Center (SLAC); in FY 2009 the SLAC facility operation completes its transition to the Basic Energy Sciences (BES) program.

In 2004, the HEPAP established the following indicators for 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."

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.46.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space			
High Energy Physics	732,434	689,331	804,960

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 3.1/2.46.00—Explore the Fundamental Interactions of Energy, Matter, Time and Space					
All HEP Facilities					
Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Goal Not Met]	Maintained and operated HEP facilities such that unscheduled downtime was on average less than 20% of the total scheduled operating time. [Met Goal]	Achieve greater than 80% average operation time of the scientific user facilities (the Fermilab Tevatron and the Stanford Linear Accelerator (SLAC) B-factory) as a percentage of the total scheduled annual operating time.	Achieve greater than 80% average operation time of the scientific user facilities (the Fermilab Tevatron) as a percentage of the total scheduled annual operating time.
Proton Accelerator-Based Physics/Facilities					
Delivered data as planned within 20% of the baseline estimate (240 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (390 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (675 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.[Met Goal]	Delivered data as planned within 20% of the baseline estimate (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron. [Met Goal]	Deliver within 20% of baseline estimate a total integrated amount of data (800 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.	Deliver within 20% of baseline estimate a total integrated amount of data (1200 pb^{-1}) to CDF and D-Zero detectors at the Tevatron.
		Delivered data as planned within 20% of the baseline estimate ($1x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility.[Met Goal]	Delivered data as planned within 20% of the baseline estimate ($1.5 x10^{20}$ protons on target) for the MINOS experiment using the NuMI facility. [Met Goal]	Measure within 20% of the total integrated amount of data ($2.0 x10^{20}$ protons on target) delivered to the MINOS detector using the NuMI facility.	Measure within 20% of the total integrated amount of data ($2.7 x10^{20}$ protons on target) delivered to the MINOS detector using the NuMI facility.
Electron Accelerator-Based Physics/Facilities					
Delivered data as planned within 20% of baseline estimate (45 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]	Delivered data as planned within 20% of baseline estimate (50 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Met Goal]	Delivered data as planned within 20% of the baseline estimate (100 fb^{-1}) to the BaBar detector at the SLAC B-factory.[Met Goal]	Delivered data as planned within 20% of the baseline estimate (150 fb^{-1}) to the BaBar detector at the SLAC B-factory. [Goal Not Met]	Deliver within 20% of the baseline estimate a total integrated amount of data (220 fb^{-1}) delivered to the BaBar detector at the Stanford Linear Accelerator (SLAC) B-factory.	
Construction/Major Items of Equipment					
Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. [Met Goal]	Maintained cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates. [Met Goal]	Achieve less than 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.	Achieve less than 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.

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, accelerator science 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 in Office of Science Regulation 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. New projects are selected through peer review and merit evaluation.

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

The HEP program in fundamental science is closely coordinated with the activities of other federal agencies, including the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA). HEP also promotes the transfer of the results of its basic research to contribute to DOE missions in areas of nuclear physics research and facilities; basic energy sciences facilities, (contributing to research in materials science, molecular biology, physical chemistry, and environmental sciences); and mathematical and computational sciences.

Validation and Verification

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

Program Assessment Rating Tool (PART)

The Department has implemented a tool to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The HEP program has incorporated feedback from OMB into the FY 2009 Budget Request and has taken or will take the necessary steps to continue to improve performance.

The HEPAP reviewed progress on the long-term HEP program goals (listed under Contribution to Strategic Goals) in 2006. They found this set of long-term goals to be appropriate, that some of the six goals have already been achieved in part, and that nearly all are likely to be achieved in the 10-year timeframe since they were established in 2004. They further recommended that new goals be established in 2008 when plans and funding profiles for new proposals would be clearer.

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the HEP program a rating of "Moderately Effective". OMB found performance improvements at Fermilab and an ongoing prioritization process. The assessment also found that HEP had developed a limited number of adequate performance measures which are continued for FY 2009. 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. The annual performance targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB previously provided HEP with three recommendations to further improve performance:

- Implement the recommendations of past and new external assessment panels, as appropriate.
- Develop a strategy and implementation plan for particle accelerator research and development, including a potential international linear collider.
- Engage the National Academies to help develop a realistic long-term plan for the program that is based on prioritized scientific opportunities and input from across the scientific community.

In response to OMB's recommendations HEP has:

- Established a Committee of Visitors (COV) that provides outside expert validation of the program's merit based review processes for impact on quality, relevance, and performance. The COV reports are available on the web (http://www.science.doe.gov/hep/HEPAPCOVReportfinal.pdf). The HEP action plans are available on the web at (http://www.sc.doe.gov/hep/OfficeofHEPResponsetoCOVreport.shtm).
- HEPAP was charged in 2006 to establish panels to assess progress toward the long-term goals of the HEP program. These goals are spelled out under the "Contribution to Strategic Goals" section above. They found the long-term goals to be appropriate, that some of the six goals have already been achieved in part, and that nearly all are likely to be achieved in the 10-year timeframe since they were established in 2004 (http://www.science.doe.gov/hep/HEPAPlongtermassessmentreport.pdf).
- The National Academies study of elementary particle physics ("EPP2010") transmitted its recommendations on the priorities of scientific opportunities in 2006. In FY 2007, HEPAP was charged to examine the options for addressing these scientific opportunities and mounting a world-class U.S. particle physics program with available resources. The HEPAP study will provide important input for establishing the strategy for HEP accelerator R&D within DOE that incorporates the challenges of a potential international linear collider.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov website. Information concerning HEP PART assessments and current follow up actions can be found by searching on "high energy physics" at http://www.ExpectMore.gov.

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 regarding the direction and management of the national high energy physics research program. HEPAP (or a subpanel thereof) 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. HEPAP subpanels are also convened to review progress and/or future plans in particular research areas or elements of the HEP program. A subpanel called the Neutrino Scientific Assessment Group (NuSAG), reporting jointly to HEPAP and the Nuclear Science Advisory Committee (NSAC), is advising DOE and NSF on specific questions concerning the U.S. neutrino program (http://www.science.doe.gov/hep/NUSAGFinalReportJuly13,2007.pdf). A HEPAP subpanel reviewing the DOE advanced accelerator R&D program reported in the summer of 2006 (http://www.science.doe.gov/hep/AARDsubpanelreportfinalamendedAug21.pdf), and one on the university HEP research programs of DOE and NSF reported in summer 2007 (http://www.science.doe.gov/hep/ugpsreportfinalJuly22,2007.pdf). These evaluations and the priorities recommended are important input in the development of the HEP strategic plan. In FY 2007, HEPAP was charged to examine the options for addressing current scientific opportunities and mounting a world-class U.S. particle physics program at various funding levels. The findings and recommendations of this HEPAP report will be submitted in FY 2008 and will be important input for setting the programmatic priorities for the U.S. HEP program that can be implemented with available resources.

The Astronomy and Astrophysics Advisory Committee (AAAC) now reports on a continuing basis to the DOE, as well as to the NSF and NASA, with advice on the direction and management of the national astronomy and astrophysics research programs. The AAAC operates similarly to HEPAP and the two advisory bodies may form joint task forces or subpanels as needed to address research issues at the intersection of high energy physics, astrophysics and astronomy, such as dark energy and dark matter. For example, Task Forces on the cosmic microwave background and dark energy reported in spring 2006, and a Scientific Assessment Group for Dark Matter submitted their report in July 2007 (http://www.science.doe.gov/hep/DMSAGReportJuly18,2007.pdf).

The National Academy of Sciences 2006 decadal survey of opportunities in high energy physics and the tools needed to realize them in the next 15 years. The committee's report, *Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics* emphasized the importance of the Large Hadron Collider (LHC) and the International Linear Collider (ILC) in the context of a broad and balanced program that also includes among its elements particle astrophysics and neutrino physics. The report is referred to colloquially as "EPP2010", and is available at http://www7.nationalacademies.org/bpa/EPP2010.html.

In 2006, DOE and NASA charged and jointly funded a National Research Council study by the Beyond Einstein Program Assessment Committee (BEPAC), which was completed in September 2007. This study assisted NASA in determining which of the five proposed NASA Beyond Einstein astrophysics missions should be developed and launched first. The proposed DOE and NASA Joint Dark Energy Mission (JDEM) was recommended to be the first mission, and DOE and NASA now plan to move forward jointly on the mission.

Facility 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.

The HEP program has also instituted a formal Committee of Visitors that provides 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 second triennial HEP Committee of Visitors review took place in summer 2007. The committee report praised the program strongly, but also pointed to several areas that could be improved.

Review and Oversight

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

The program also conducts regular 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 laboratory program reviews, to assess in detail the quality and relevance of the specific proposal. In addition, the HEP program office began in FY 2004 to conduct regular, dedicated reviews of operations at its major user facilities in order to maintain high standards of performance and reliability. The HEP program office also participates in the annual SC reviews of each of its laboratories, and conducts *ad hoc* reviews of particular HEP research topics on an as-needed basis.

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.

Significant Program Shifts

After a very successful eight-year run, operation of the SLAC B-factory was completed in FY 2008. Funding is provided in FY 2009 to support analysis of data collected at the B-factory and for safe ramp-down of the facility. The transfer of responsibility for the SLAC linac to Basic Energy Sciences is completed in FY 2009.

Proton Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Proton Accelerator-Based Physics			
Research	110,021	109,238	114,528
Facilities	233,612	259,587	305,049
Total, Proton Accelerator-Based Physics	343,633	368,825	419,577

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.

The Proton Accelerator-Based Physics subprogram exploits U.S. leadership at the energy frontier by conducting experimental research at high energy proton collider facilities. This experimental research program will determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and will search for the first clear evidence of new physics beyond the Standard Model.

The Proton Accelerator-Based Physics subprogram also includes precise, controlled measurements of basic neutrino properties performed at accelerator facilities. These measurements, performed with neutrino beams generated from primary proton beams, will provide important clues and constraints to the new world of matter and energy beyond the Standard Model.

The most immediate goal on the particle physics roadmap is to fully understand the unification of the electromagnetic and weak nuclear interactions into a single, "electroweak" force. This is expected to occur at an energy scale of about one trillion electron volts or 1 TeV. The Standard Model has successfully explained almost all particle physics phenomena below 1 TeV in energy, but beyond that energy range a new physical mechanism must be present to prevent Standard Model predictions from becoming unphysical. Originally it was proposed that a single Higgs boson is the solution to this "TeV scale" problem, but newer theories such as supersymmetry, extra hidden dimensions, and technicolor could also solve the TeV scale problem in the Standard Model, either in place of or in combination with, one or more Higgs bosons. No matter which of these theories is shown to be correct, it will provide new insights into the fundamental nature of matter, energy, space, and time. One thing is clear, however: new physics must occur at the Terascale.

Because of the high energy of the collisions at the Tevatron Collider (2 TeV) and the LHC (14 TeV), and the fact that the particles interact differently at different energies, these facilities can be used to study a wide variety of scientific issues. All of the six known types of quarks can be produced in these interactions, but the heaviest, the top and bottom quarks, are of the greatest interest. Most of the force-carrying particles are also produced in these collisions, and if the masses of predicted—but as yet unobserved—particles, such as the Higgs boson or supersymmetric particles are small enough, they will also be discovered. Whether the Tevatron or the LHC is the first accelerator to observe new physics at the TeV scale will depend on the configuration that nature has chosen for these phenomena.

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

The major activities under the Proton Accelerator-Based Physics subprogram are the research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab; the neutrino research program using the NuMI/Main Injector Neutrino Oscillation Search (MINOS) facility at Fermilab and at the Soudan Mine site in Minnesota; the research programs of ATLAS and CMS at the Large Hadron Collider (LHC) at CERN program; and the maintenance and operation of these experimental facilities.

Physics at the energy frontier is the primary thrust of the Proton Accelerator-Based Physics subprogram. In FY 2009, the energy frontier moves to the Europe with the start-up of LHC operations. U.S. participation in the LHC program will enable U.S. high energy physicists to remain key players at the new energy frontier. While the LHC experiments will be just beginning to acquire experience with their first data, the well-understood CDF and D-Zero experiments at the Tevatron will continue their searches for the Higgs and precision measurements of known particles—such as the mass of the W boson and the top quark—that will indicate where the Higgs or other new physics is likely to be found. Less than 100 top quarks were accumulated and studied during the previous Tevatron collider run from 1992 to 1996. The new run (started in 2001) has already produced over an order of magnitude more top quarks, and will provide far more precise measurements of its mass, spin, and couplings. Recent measurements of the top mass have reached a precision very near 1% and the W mass a precision near 0.05%, together placing increasingly strong constraints on the mass of a Standard Model Higgs.

Today, neutrino physics presents one of the most promising avenues to probe for extensions of the Standard Model. In the last decade, a number of interesting new results have been reported by several different experiments, including the Super-K and KamLAND experiments in Japan and the Sudbury Neutrino Observatory (SNO) experiment in Canada. These experiments provide compelling evidence that neutrinos do have mass and do change their identities (the different neutrino species "mix") as they travel. These properties of neutrinos are neither required nor predicted by the Standard Model. One of the unique opportunities in the Proton Accelerator-Based Physics subprogram is to explore and make high precision measurements of neutrinos generated at dedicated proton beam facilities in a well-controlled environment (e.g., the NuMI beam at Fermilab). The NuMI/MINOS program is making decisive controlled measurements of fundamental neutrino properties, including neutrino mixing, and will provide important clues and constraints to the theory of matter and energy beyond the Standard Model.

The National Academy of Sciences "EPP2010" report recommended a diverse HEP program using a variety of tools to attack the exciting opportunities in elementary particle physics, including a staged internationally coordinated program in neutrino physics. One of those opportunities, the observation of electron neutrinos from a muon neutrino beam, can be met by the proton accelerator-based research program. A new detector optimized to detect electron neutrinos, NuMI Off-axis Neutrino Appearance (NOνA) Detector will utilize the NuMI beam.

Highlights

Recent accomplishments include:

- Important recent physics results from the CDF and D-Zero detectors at Fermilab include the production of single top quarks, one of the rarest collision processes ever observed at a hadron collider; a new measurement of the top quark mass, which when combined with a new precise measurement of the W mass places increasingly strong bounds on the Standard Model Higgs mass; the first observation of events that simultaneously produce a W boson and a Z boson, an important milestone in the search for the Higgs boson; and the discovery of new particles containing quarks from each of the three different families. The innovative analysis methods employed by CDF and D-Zero scientists, and thorough understanding of detector performance and backgrounds displayed in these results, bode well for future discoveries.

- The MiniBooNE experiment reported its findings and resolved questions about results from the Liquid Scintillator Neutrino Detector (LSND) experiment in the 1990's. All neutrino oscillation results from around the world could be explained by a simple model of three types of neutrinos oscillating among themselves. MiniBooNE researchers showed conclusively that the LSND results could not be due to simple neutrino oscillations, and that a proposed new type of neutrino does not exist.

The major planned efforts in FY 2009 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, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley National Laboratory (LBNL), 56 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2009 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. In particular, the direct experimental exclusion of a Higgs boson with a mass near 160 GeV/c2 should be within reach soon, while searches for a Higgs boson with lighter mass will require more data. The Tevatron experiments will collect data in FY 2009 that will give the two experiments access to extremely rare subatomic processes, including access to a significant region of the expected Higgs mass range.
- *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 2009 will be data taking and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics. The experiment is planned to run through FY 2010 to achieve its ultimate sensitivity, about a factor of two improvement over its current result. A new experiment, Main Injector Experiment ν-A (MINERνA), which will make precision measurements of neutrino interaction rates in the NuMI beam (an important input to analyze MINOS and NuMI Off-axis Neutrino Appearance [NOνA] data), continues fabrication in FY 2009.
- *A new detector for neutrino physics.* Final engineering design began in FY 2007 for a new Major Item of Equipment, the NOνA Detector which will use the NuMI beam from Fermilab to directly observe and measure the transformation of muon neutrinos into electron neutrinos over distances of hundreds of miles. The project also includes improvements to the proton source to increase the intensity of the NuMI beam. The occurrence of these particular neutrino "flavor" changes is expected to be much rarer than the phenomenon that MINOS is studying. Funding for NOνA was suspended by Congress in FY 2008. The previously planned funding profile has been shifted by one year, and a revised project plan is under development.

- *The U.S. LHC research program*. In FY 2009, U.S. researchers will play a leadership role in the physics discoveries at the high energies enabled by the LHC. Achieving this goal requires effective integration of U.S. researchers in the LHC detector calibration and data analysis efforts, and implementation and optimization of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Maintenance of U.S.-supplied detectors for LHC experiments at CERN will continue.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Research	**110,021**	**109,238**	**114,528**
▪ **University Research**	**51,593**	**53,749**	**56,623**

The HEP university research program consists of groups at more than 60 universities doing experiments at proton accelerator facilities. These university groups plan, build, execute, analyze, and publish results of experiments; develop the physics opportunities and preliminary designs for future experiments; and train graduate students and postdoctoral researchers. University-based scientists typically constitute about 75% of the personnel needed to create, run, and analyze an experiment, and they usually work in collaboration with other university and laboratory groups. University personnel are fully integrated into the operations of the detector facilities, performing various service functions, and these facilities could not operate without them. University-based research efforts are funded in a manner based on peer review, and funded at levels commensurate with the effort needed to carry out the experiments.

In FY 2009, the overall level of university research support in this subprogram increases significantly to reflect anticipated shifts towards LHC research, as the electron accelerator-based research program begins to wind down with the completion of B-factory operations. This increase in LHC research activity will occur while maintaining strong participation in the Tevatron and neutrino physics programs. Strong participation of university physicists is needed to carry out the collider and neutrino program at the Tevatron during FY 2009. There will be healthy scientific competition between completion of the Run II of the Tevatron Collider program and commencement of the LHC experiments. The detailed funding allocations will take into account the quality of research as well as the involvement of university-based research groups in the targeted physics research activities. These include research efforts related to the Tevatron experiments CDF and D-Zero; the NuMI neutrino experiments MINOS, NOνA, and MINERνA; and U.S. participation in the LHC research program. U.S. university researchers are also contributing to a new accelerator-based neutrino oscillation experiment (T2K) in Japan. This experiment utilizes neutrino beams from the Japanese proton accelerator facility, measured both in a nearby detector and in the Super-Kamiokande detector, to study neutrino oscillations in a way complementary to NOνA. In FY 2009, $1,000,000 is requested to complete fabrication of the MIE project to build a detector for the T2K beam line (TPC $4,680,000).

	FY 2007	FY 2008	FY 2009
▪ **National Laboratory Research**	**57,229**	**54,441**	**56,665**

The national laboratory research program consists of groups at several laboratories participating in experiments at proton accelerator facilities. These groups are involved in all phases of the experiments, with the focus of the physics analysis being similar to that of the university groups

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

described above. They also 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 provided by independent peer reviewers. Proton accelerator research activities concentrate on experiments at the Tevatron complex (collider and neutrino physics programs) at Fermilab and the LHC at CERN.

The increase in the support of laboratory research in FY 2009 will enhance participation of laboratory physicists in the A large Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) experiments as LHC operations and data analysis begin. Strong involvement of physicists from the national laboratories will also be needed to carry out the research program at the Tevatron during FY 2009, as there will be a competition in resources between the completion of Run II of the Tevatron Collider and commissioning of the LHC experiments. The High Energy Physics program will monitor progress in these areas, and balance resources so as to optimize the national program.

The Fermilab research program includes data taking and analysis of the CDF, D-Zero, and MINOS experiments; the CMS research and computing program; and research related to the new neutrino initiatives, such as the NOνA and MINERνA experiments. This research by physicists at the host laboratory provides the necessary close linkages between the Research and the Facilities activities in the Proton Accelerator-Based Physics subprogram.

Research at LBNL consists of a large and active group in the ATLAS research and computing program. The BNL research group will focus on the ATLAS research and computing program, completing data taking and analysis of the D-Zero experiment, and a small effort on the MINOS experiment and research related to future neutrino initiatives. The research group at ANL will be working on data taking and analysis of the CDF experiment, the ATLAS research and computing program, data taking and analysis of the MINOS detector, and research related to the new neutrino initiatives, such as the NOνA experiment. A research group from SLAC joined the ATLAS experiment in 2006 and will be actively engaged in LHC research and data analysis.

▪ **University Service Accounts**	**1,199**	**1,048**	**1,240**

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 Fermilab. Funding for these university service accounts is maintained at about the FY 2007 level, reflecting the anticipated need.

Facilities	**233,612**	**259,587**	**305,049**
▪ **Tevatron Complex Operations**	**119,976**	**144,974**	**157,550**

Operations at Fermilab will include operation of the Tevatron accelerator complex for both collider and neutrino physics programs, including two collider detectors and a neutrino experiment. This will be a major physics run for the D-Zero and CDF detectors with the higher intensity available from the upgraded Main Injector. The Tevatron performance has continued to improve according to plan through FY 2007 and this is to be one of the major data collection periods for the collider experiments pursuing physics topics from the energy frontier facility.

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

Tevatron operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron collider operations. This running mode will be primarily for the physics data taking of the MINOS experiment using the NuMI beamline.

In FY 2009, the increase in this category is slightly above constant level of effort to ensure the successful completion of Run II. Efforts will be increased in accelerator operations to maintain the Tevatron complex and in detector operations to handle the large datasets expected to be produced in FY 2009. The operations and commissioning activities for the NuMI proton improvement plan to increase the intensity of the proton source from 250 kW to about 400 kW will be completed in FY 2008.

The proposed funding will support operations at the Department's two major high energy physics facilities both at Fermilab: the Tevatron Collider and the NuMI neutrino beamline. The Tevatron Collider provided a total of 4,620 hours of beam time in FY 2007 for a research community of about 700 U.S. scientists in HEP and another 700 researchers from foreign countries, testifying to the fact that this is a unique, world-leading experimental facility. Operation of NuMI began in FY 2006 and served more than 250 researchers, of whom about two-thirds are U.S. researchers. Approximately 500 researchers world-wide participate in Fermilab's other experimental and theoretical research and R&D programs. The FY 2009 request will support facility operations at Fermilab to provide about 5,040 hours of beams for the Tevatron Collider and for NuMI, including an allowance for increased power costs and incremental upgrades.

	FY 2007	FY 2008	FY 2009
Tevatron Complex[a] (including NuMI)			
Optimal hours (estimated)	4,560	5,400	5,400
Planned Operating Hours	4,560	5,040	5,040
Achieved Operating Hours	4,620	N/A	N/A
Unscheduled Downtime	<17%	N/A	N/A
Total Number of Users	2,160	2,160	2,160

- **Tevatron Complex Improvements** **41,515** **34,070** **64,300**

The funding in this category includes funds for general plant projects (GPP) and other infrastructure improvements at Fermilab, funding for accelerator improvements, experimental computing expansion and other detector support, and new detector fabrication. Accelerator improvements to increase the luminosity performance of the Tevatron Collider were completed in FY 2006, and the laboratory began to focus on improving the intensity of the NuMI beamline beyond its design power of 250 kW via a phased plan of incremental upgrades. The first phase of these improvements concludes in FY 2008 and will support deployment and commissioning of these improvements to increase the intensity of the proton source to about 400 kW.

[a] Tevatron and NuMI operations run in parallel.

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

After the completion of Tevatron Collider Run II, it will be possible to adapt portions of the existing collider complex to support operations of the NuMI beam-line at even higher intensity than is possible during Run II. Reconfiguration of the Recycler, which currently serves as a storage ring for antiprotons, can raise the beam power to the NuMI target from 400 kW to 700 kW. Improvements to the cooling, shielding and power supplies in the Booster, Main Injector, and NuMI beam-line would also be done to support the higher beam intensity.

Since the increase in neutrino intensity that can be achieved with this reconfiguration will be very important to support the physics goals of the NuMI Off-axis Neutrino Appearance (NOνA) Detector, this collection of upgrades and improvements is part of the scope of the NOνA project in order to ensure appropriate project management oversight and integration. Accelerator upgrade activities are mostly contained in the NOνA MIE to allow for optimization of the physics delivered by the project within the overall budget.

The NOνA detector (preliminary TPC $270,000,000) is optimized to identify electron-type neutrinos and, using the NuMI beam from Fermilab it will observe for the first time the transformation of muon-type into electron-type neutrinos. It will also make important indirect measurements from which we may be able to determine the mass hierarchy for the three known neutrino types (i.e., whether there are two "light" and one "heavier" type of neutrino or vice versa), which will be a key piece of information in determining the currently unknown masses of neutrinos. The project includes the very large "far" detector (approximately football-field size and five stories high), the far detector enclosure, its associated electronics and data acquisition system, and a small "near" detector on the Fermilab site.

The fabrication of the NOνA MIE (TEC) ramps up significantly in FY 2009 after funding was suspended in FY 2008, just prior to the project being baselined. A revised baseline which takes into account the actual FY 2008 spending and a revised project schedule will be completed early in 2008. Other Project Cost funding for the NOνA project in FY 2009 includes the planned cooperative agreement with the University of Minnesota, to build an enclosure for the detector and participate in the NOνA research program, along with final design of detector elements. This project is planned to be completed and taking data in FY 2013.

	FY 2007	FY 2008	FY 2009
NOνA MIE (TEC)	1,000	—	7,000
NOνA (OPC)—R&D and cooperative agreement	6,970	5,970[a]	30,000
Total, NOνA (TPC)	7,970	5,970	37,000

Also included in this category is $4,900,000 in FY 2009 to continue fabrication of the MINERνA MIE (TEC $10,700,000). This is a small experiment in the MINOS near detector hall at Fermilab that will measure the rates of neutrino interactions with ordinary matter. This is

[a] The FY 2008 Energy and Water Development and Related Agencies Appropriation provided no funds for NOνA activities, but at the time the appropriation had been signed $5,970,000 had already been obligated under the Continuing Resolution. Steps were taken to cease spending immediately after passage of the Appropriation. It may be possible to deobligate a portion of the $5,970,000; if so, this amount would be reduced and the funding shifted to another activity.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

important data for MINOS and other neutrino experiments including NOνA, and can be measured with much better precision than previous experiments using the powerful NuMI beam. This project is planned to be completed and taking data in FY 2010.

	FY 2007	FY 2008	FY 2009
▪ **Large Hadron Collider Project**	**3,180**	**—**	**—**
• **LHC Detectors**	**3,180**	**—**	**—**
♦ **ATLAS Detector, Operating Expenses**	**1,880**	**—**	**—**
♦ **CMS Detector**	**1,300**	**—**	**—**
Operating Expenses	**50**	**—**	**—**
Capital Equipment	**1,250**	**—**	**—**

Under the agreement with CERN regarding U.S. participation in the LHC program, DOE has provided $450,000,000 to the LHC accelerator and detectors (with an additional contribution of $81,000,000 from the NSF). The DOE total contribution was separated into detectors ($250,000,000) and accelerator ($200,000,000), with the accelerator funding consisting of $88,500,000 for direct purchases by CERN from U.S. vendors, and $111,500,000 for fabrication of components by U.S. laboratories.

A significant problem did occur in 2007 during commissioning with one of the U.S. supplied accelerator components, an inner triplet magnet, built by Fermilab; it failed during a pressure test at CERN. The response of the laboratory and the project management team to the problem was effective and efficient; a remediation was developed and carried out, and all components have now been successfully tested. No delays to the overall LHC schedule were incurred. The first LHC collisions are expected in 2008.

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. Over 1,000 U.S. scientist members of the U.S.-ATLAS and the U.S.-CMS detector collaborations, or the U.S.-LHC accelerator consortium, will be supported by the DOE and NSF core research programs by FY 2009.

The overall U.S. LHC Project reached a status of 98% complete by the end of FY 2006, in compliance with the “CD-4a” project-completion requirement prescribed by the DOE. Essentially all of the equipment is already at CERN, and the remaining portion of the accelerator project was completed in 2006. The two detector projects, tied to the final stages of the CERN schedule, will be completed before the end of FY 2008. The latter activities are related primarily to the final assembly, testing, and installation of the completed detectors, as well as to the purchase of computing hardware for data acquisition. Under the current schedule, completion of these two detector projects will take place in early calendar year 2008, in full agreement with the U.S. DOE deadline for the completion of the project. The overall result of previous delays in the CERN schedule was a stretch-out by two years in the planned U.S. contributions to the LHC detectors. The final cost of each detector remains unchanged, and the final year of DOE funding for all aspects of the U.S. participation in fabrication of the LHC was FY 2007.

U.S. LHC Accelerator and Detectors Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation (Detectors)
	Accelerator	Detectors	Total	
1996[a]	2,000	4,000	6,000	—
1997[a]	6,670	8,330	15,000	—
1998[a]	14,000	21,000	35,000	—
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	27,243	31,627	58,870	16,370
2002	21,303	27,697	49,000	16,860
2003	21,310	37,900	59,210	9,720
2004	29,330	19,470	48,800	—
2005	21,447	11,053	32,500	—
2006	—	7,440	7,440	—
2007	—	3,180	3,180	—
Total	200,000[b]	250,000	450,000	81,000

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
▪ **Large Hadron Collider Support**	**56,820**	**63,622**	**72,450**

The U.S. LHC effort is one of the highest priority components of the HEP program, endorsed repeatedly by HEPAP, and by the recent National Academy of Sciences study (EPP2010). With LHC turn-on occurring in 2008, the U.S. LHC program, jointly supported by the DOE and the NSF, will be in a critical phase in FY 2009. An increase of almost 14% in DOE support above FY 2008 is planned. This includes increased costs for Fermilab direct program support. The main use of the resources will be for LHC software and computing, and pre-operations and maintenance of the U.S.-built systems that are part of the LHC detectors. The U.S. also participates in accelerator commissioning and accelerator physics studies using the LHC, along with R&D for potential future upgrades to both the machine and the detectors. Most of the increase in FY 2009 funding is for accelerator R&D aimed at supporting LHC upgrades. With first data anticipated in 2008, a high priority will be on the ramp-up of operations in FY 2009.

[a] The FY 1996 and FY 1997 LHC funding was for R&D, design, and engineering work in support of the proposed U.S. participation in LHC. Beginning in FY 1998 funding was used for: fabrication of machine and detector hardware, supporting R&D, prototype development, and purchases by CERN from U.S. vendors
[b] Includes $111,500,000 for LHC supporting R&D and accelerator components to be fabricated by U.S. laboratories and $88,500,000 for purchases by CERN from U.S. vendors.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
• **LHC Software and Computing**	**21,759**	**26,327**	**26,960**

The LHC software and computing effort will enable U.S. physicists to analyze the vast quantities of LHC data and empower them to play a leading role in exploiting the physics opportunities presented by the LHC. The LHC Software and Computing program will also be in a critical stage in FY 2009, when the combination of software development, facilities hardware and support, and grid computing must come together and operate smoothly. Prior to FY 2008, the U.S. effort focused on data and service challenges, with testing of the hardware and infrastructure needed for full LHC data analysis using professional-quality software on simulated data. These systems have to mature rapidly into fully functional production systems over a period of one to two years. The funding will provide for 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 play a central role. Grid computing solutions will continue to be integrated in the LHC computing model, building on the tools provided by the Scientific Discovery through Advanced Computing (SciDAC) Open Science Grid project, and providing U.S. researchers the access and computing power needed to analyze the large and complex LHC data. In FY 2009, full-scale analysis with physics-quality data will form the final stress test for the completed systems, and will likely indicate areas where the analysis model can be better optimized.

• **LHC Experimental Support**	**24,061**	**25,377**	**27,490**

Funding is provided for operations and maintenance of the U.S.-built LHC detector subsystems as well as increasing support for generic detector R&D with specific focus on detector technologies needed to accommodate a possible LHC upgrade in luminosity. This effort will support the continuing development and deployment of tools for control, calibration, and exploitation of LHC data, including remote detector monitoring and control systems. These tools will facilitate remote participation by U.S. physicists in the operation of the LHC detectors.

Support will also be provided for technical coordination and program management, both at the participating U.S. national laboratories and at CERN.

• **LHC Accelerator Research**	**11,000**	**11,918**	**18,000**

The U.S. LHC Accelerator Research Program (LARP), supported solely by the DOE, will continue to focus R&D on producing full-scale accelerator-quality magnets with the highest possible sustained magnetic fields. This R&D will provide important technical data to CERN for management decisions on possible future LHC accelerator upgrades to increase luminosity. In FY 2009, funding is increased by approximately 50%, to speed fabrication of advanced prototypes of state-of-the-art LHC interaction region magnets made of optimized niobium-tin (Nb_3Sn) superconductor material. Special instrumentation is also being provided for collimation and monitoring of the LHC beams that will play an important role during the accelerator commissioning phase.

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
▪ **Alternating Gradient Synchrotron (AGS) Support**	**650**	**644**	**650**

Funding continues for long-term decontamination and decommissioning (D&D) of the AGS facility, whose operations as a HEP user facility at BNL were terminated at the end of FY 2002.

▪ **Other Facilities**	**11,471**	**16,277**	**10,099**

Includes funding for private institutions and other government laboratories and institutions that participate in high energy physics research, as well as recurring contributions to general program operations activities, such as the federal laboratory consortium, financial auditing, support for internal and external program and project reviews, personnel support under the Intergovernmental Personnel Act, and technical consultation on programmatic issues. This category also includes funding to respond to new opportunities and unexpected changes in facilities operations and support.

In FY 2009, funding in this category includes $1,154,000 for General Purpose Equipment at LBNL for landlord related activities and $2,230,000 for LHCNet, the transatlantic data link between the U.S. and CERN.

Total, Proton Accelerator-Based Physics	**343,633**	**368,825**	**419,577**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Research	
▪ Funding for university-based research in this subprogram increases to support the expanding research program at the LHC. Additional funds are included to support increased university grantee research expenses associated with travel to CERN.	+2,874
▪ Funding for laboratory-based research in this subprogram increases to support the research program that is ramping up in FY 2009 at the LHC. It maintains support for ongoing scientist effort at the Fermilab Tevatron Collider.	+2,224
▪ Increase in university service accounts reflects the anticipated need, based on the most recent actual costs in this category.	+192
Total, Research	+5,290
Facilities	
▪ Tevatron Complex Operations receives increased support to maintain constant level of effort in order to ensure a successful completion of Run II.	+12,576
▪ Tevatron Complex Improvements increase significantly because the NuMI Off-axis Neutrino Appearance experiment (NOvA) MIE is largely contained in this budget category, and fabrication activities for both the far detector and the detector enclosure ramp-up in FY 2009.	+30,230

	FY 2009 vs. FY 2008 ($000)
▪ LHC Support funding increases to provide approximately constant level-of-effort in support of LHC detector operations, planned increases for computing hardware to enable U.S. researchers to keep pace with increasing LHC datasets, and accelerated fabrication of prototype niobium-tin superconducting interaction region magnets to demonstrate the feasibility of LHC luminosity upgrades.	+8,828
▪ Funding for AGS Operations/Support restores the appropriate level for this activity.	+6
▪ Funding for Other Facilities support decreases as GPP funding at LBNL is transferred to the Science Laboratories Infrastructure program ($-4,490,000) along with a decrease in funding held pending completion of peer review and/or programmatic decisions ($-1,688,000).	-6,178
Total, Facilities	**+45,462**
Total Funding Change, Proton Accelerator-Based Physics	**+50,752**

Electron Accelerator-Based Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Electron Accelerator-Based Physics			
Research	22,314	22,063	22,952
Facilities	78,970	43,531	25,820
Total, Electron Accelerator-Based Physics	101,284	65,594	48,772

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.

The Electron Accelerator-Based Physics subprogram utilizes accelerators with high-energy and ultra-precise beams to create and investigate matter at its most basic level. It was the electron accelerator at SLAC that, in the 1960's, first identified the existence of quarks as the inner constituents of the proton and neutron. During the 1980's, electron accelerators—in tandem with proton machines—were instrumental in establishing the Standard Model as the correct and precise theory of particle interactions.

Over the last few years, the electron B-factory at SLAC has provided precision measurements of how matter and antimatter behave differently in the decay products of B-mesons. This asymmetric behavior is called "CP [charge-parity] violation" and is considered by physicists to be vital to understanding why the universe appears to be predominantly matter, rather than equal quantities of matter and antimatter, one of the greatest puzzles we face in comprehending the universe.

While electron accelerators can be used to study a wide variety of physics topics, the Electron Accelerator subprogram is currently focused on the study of charm and bottom quarks and the tau lepton. These particles are all heavier than the particles of everyday matter and well suited for studying rare processes. The most interesting of these processes is CP violation.

CP violation has been observed in the decays of particles containing strange quarks (K mesons) and most recently in particles containing bottom quarks (B mesons). After the observations of CP violation in B mesons were made early in this decade at the SLAC B-factory and a similar accelerator at the Japanese national laboratory for high energy physics, the High Energy Accelerator Research Organization (KEK) B-factory [KEK-B], it has been possible to do a systematic study of the process and test whether our current theoretical explanation of CP violation, the Standard Model, is correct. This ongoing study requires both new measurements of CP violation in other B meson decays, as well as measurements of other properties of particles containing bottom or charm quarks. The measurements of these other properties have been used as inputs to the theoretical calculations of CP violation, as our current knowledge of those properties limits our understanding of CP violation.

In addition to studies of CP violation, the BaBar experiment at the SLAC B-factory has pursued a broad program of research on particles containing bottom or charm quarks. The Belle experiment at KEK-B has carried out a similar program, with a small number of U.S. university researchers participating. There has been regular cooperation as well as competition between the BaBar and Belle experiments, leading to more precise measurements and a better understanding of the experimental results. The

CLEO-c experiment at the Cornell Electron Storage Ring (CESR) has been concentrating on certain measurements of particles containing charm quarks that are difficult to do at the B-factory. These results test theories used to interpret the CP violation measurements and to provide key inputs to the physics analyses done at the B-factory. The CLEO-c research program will be extended at the recently upgraded Beijing Electron Positron Collider to improve precision measurements of charm quarks and tau leptons.

In FY 2009, the B-factory is in a ramp-down mode, following completion of its scientific program in FY 2008.

Highlights

Recent accomplishments include:

- In FY 2007, the SLAC B-factory delivered 90 fb^{-1} (inverse femtobarns) of which the BaBar detector recorded 86.5 fb^{-1}. The BaBar collaboration analyzed and presented the latest results at the major biennial summer research conference in 2007. The quantum mixing of D-zero particles with their anti-particles was discovered, along with unexpected particle resonances which are challenging the conventional picture of how quarks and gluons form stable bound states.

The major planned efforts in FY 2009 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 2009 this effort will focus on final analysis with the upgraded accelerator and detector. The physics issues to be addressed include expanding our understanding of CP violation in many particle decay modes.
- *The research program at other electron accelerator facilities.* This program complements the B-factory/BaBar efforts and consists of a group of experimental research activities using the CESR and the KEK-B electron accelerator facilities. A total of 4 U.S. university groups work at KEK-B, and 22 U.S. university groups work at CESR. CESR, operated by the NSF, also completes running in FY 2008. In FY 2009, the work will concentrate on the final analysis of data taken at the CESR. A smaller effort will be devoted to operations of the Belle detector at KEK-B in Japan and analysis of the data taken.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Research	**22,314**	**22,063**	**22,952**
▪ **University Research**	**10,968**	**11,176**	**11,576**

The HEP university research program includes groups at about 40 universities doing experiments at electron accelerator facilities. These university groups analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and postdoctoral researchers. The 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.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

U.S. university scientists constitute about 50% of the personnel needed to analyze the BaBar experiment at the B-factory, and they work in collaboration with groups from national laboratories and foreign institutions. They are fully integrated into the operations of the detector facility, and perform many service functions for the detector.

The university program also supports groups that work at CESR at Cornell University; and groups that work at the KEK-B accelerator complex in Japan. The CLEO-c experiment at CESR is concentrating on certain precise measurements of particles containing charmed quarks that are difficult to perform at the B-factory. There is regular cooperation, as well as competition between the SLAC and KEK experiments, which has led to better data analysis and more precise results. University-based research efforts will be selected based on peer review.

In FY 2009, funding for university-based research in this subprogram continues at approximately a constant level-of-effort to complete analysis of physics data from BaBar and CLEO-c. The detailed funding allocations will take into account the involvement of university-based research groups in targeted physics research activities. These include research efforts related to BaBar research.

▪ **National Laboratory Research**	**11,153**	**10,777**	**11,196**

The national laboratory research program consists of groups at several laboratories participating in experiments at electron accelerator facilities with a physics program similar to the university program described above. The experimental research groups from national laboratories provide invaluable service in the operation of the detector as well as analysis of the data. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. The experimental research group from SLAC participates in all phases of the experiments. Because they are embedded in the laboratory structure, they provide invaluable service in the operation and maintenance of the detector as well as reconstruction and analysis of the data. The experimental research group at LBNL makes significant contributions to the physics analysis of the data and the computing system needed to reconstruct the data into physics quantities used for analysis. The LLNL research group contributed to the fabrication of the BaBar detector and is now primarily engaged in data analysis.

In FY 2009, laboratory-based research in this subprogram continues at approximately a constant level-of-effort to complete analysis of physics data from BaBar and CLEO-c. Overall SLAC will continue to maintain strong participation in the B-factory research program, which will be entering a two to three year period of intense analysis of the entire B-factory data set, while research groups at LBNL and LLNL have mostly transitioned to other activities. BaBar analysis will be the priority HEP research program at SLAC in FY 2009. A small electron accelerator-based research program at Fermilab is devoted to physics studies of the ILC.

▪ **University Service Accounts**	**193**	**110**	**180**

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 SLAC.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Facilities	**78,970**	**43,531**	**25,820**
▪ **B-factory Operations**	**60,820**	**31,681**	**22,400**
• **Linac Operations**	**36,400**	**10,717**	**—**
• **Other B-factory Operations**	**24,420**	**20,964**	**22,400**

Funding for operations supports the transition of the B-factory accelerator complex to a safe and stable maintenance mode, and the planning and initiation of decontamination and decommissioning activities. This funding category also supports ongoing BaBar computing operations and data analysis. No funding is requested within this activity for SLAC Linac operations, as support of Linac Coherent Light Source (LCLS) commissioning is entirely underwritten by the Basic Energy Sciences (BES) program (see the Facilities section of the BES Materials Sciences and Engineering subprogram).

B-factory operations ended in FY 2008 with a significantly shortened physics run due to budget constraints in the Energy and Water Development and Related Agencies Appropriations Act. Faced with a very limited final run for the B-factory, BaBar decided to optimize their science output by moving the B-factory energy to a nearby resonance, slightly below the B meson production threshold where they usually operate to study CP violation and B meson decays. This strategy will generate a unique data set that can be used for detailed studies of QCD processes, rather than only marginally adding to the large existing data set.

The B-factory provided a total of about 4,200 hours of beam time in FY 2007 for a research community of about 300 U.S. scientists in HEP and a comparable number of users from foreign countries. SLAC also hosts approximately 500 researchers world-wide who are active in its other experimental and theoretical research and R&D programs. FY 2008 is the last year of HEP facility operations at SLAC for the B-factory, though analysis of the accumulated data will continue for a few more years. The B-factory will run for only 1,300 hours in FY 2008 instead of 5,720 hours planned in the FY 2008 request, due to the FY 2008 HEP appropriation being 12% lower than the request.

B-factory	FY 2007	FY 2008	FY 2009
Optimal hours (estimated)	5,200	5,850	—
Planned Operating hours	4,800	1,300	—
Achieved Operating Hours	4,200	N/A	—
Unscheduled Downtime	<22%	N/A	—
Total Number of Users	1,100	1,000	800

▪ **B-factory Improvements**	**18,150**	**11,850**	**3,420**
• **Linac Improvements**	**14,900**	**9,100**	**—**
• **Other B-factory Improvements**	**3,250**	**2,750**	**3,420**

Funding is provided for the necessary enhancement of computing capabilities in order to support the timely analysis of the flood of data the B-factory has provided over the past few years. Activities in

	FY 2007	FY 2008	FY 2009
this category also include a contribution to site-wide infrastructure, as well as general maintenance activities.			
Total, Electron Accelerator-Based Physics	**101,284**	**65,594**	**48,772**

(dollars in thousands)

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Research	
▪ Funding for university-based research in this subprogram continues at approximately a constant level-of-effort to complete analysis of physics data from BaBar and CLEO-c.	+400
▪ Funding for laboratory-based research in this subprogram continues at approximately a constant level-of-effort to complete analysis of physics data from BaBar and CLEO-c.	+419
▪ Increases in university service accounts reflect the anticipated need.	+70
Total, Research	**+889**
Facilities	
▪ Funding for B-factory Operations is significantly reduced to reflect the completion of HEP operations at this facility in FY 2008. Activities in FY 2009 will be focused on the ramp-down of facility operations to a "minimum maintenance" configuration, along with detailed planning for safe and efficient dismantling and decommissioning of the B-factory accelerator and detector.	-9,281
▪ Funding for B-factory Improvements is significantly reduced to reflect the completion of HEP operations of this facility in FY 2008. The main activity supported in FY 2009 will be computing support to enable researchers to complete analyses of the large B-factory dataset.	-8,430
Total, Facilities	**-17,711**
Total Funding Change, Electron Accelerator-Based Physics	**-16,822**

Non-Accelerator Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Non-Accelerator Physics			
University Research	18,703	18,960	19,749
National Laboratory Research	31,466	33,107	33,883
Projects	8,796	20,837	32,230
Other	1,690	1,295	620
Total, Non-Accelerator Physics	60,655	74,199	86,482

Description

The mission of the Non-Accelerator Physics subprogram is to foster fundamental research in elementary particle physics using naturally occurring particles and phenomena that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those topics in particle physics that cannot be investigated completely with accelerators, or are best studied by other means. These activities—including the search for, or measurement of, dark matter and dark energy—have provided experimental data, new ideas, and techniques complementary to those provided by accelerator-based research. These research activities align with the program mission to understand the universe at its most fundamental level. Non-Accelerator Physics is playing an increasingly important role in High Energy Physics, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles and phenomena. University and laboratory scientists in this subprogram investigate topics such as dark matter, dark energy, neutrino properties, proton decay, the highest energy cosmic rays, and primordial antimatter. These areas of research probe well beyond the Standard Model of particle physics and offer possibilities for discovery of significant new physics.

Some of the non-accelerator-based particle sources used in this research are neutrinos from the sun, galactic supernovae, terrestrial nuclear reactors, and cosmic rays striking the earth's atmosphere. Other sources are the light (photons) emitted by supernovae, galaxies and other celestial objects. These experiments utilize particle physics techniques and scientific expertise, as well as the infrastructure of our national laboratories; and are often located at remote sites, such as in deep underground laboratories, on mountain tops, across deserts, or in space, either as dedicated satellites or as instruments attached to NASA facilities such as the International Space Station.

Research and Facilities

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

The Non-Accelerator Physics subprogram includes support for special facilities and research groups to perform experimental measurements. While research activities (including remote site operations of Non-Accelerator Physics experiments) are covered under the Research activities, the Projects activity in the Non-Accelerator Physics subprogram supports the technical R&D, engineering and design, and fabrication of detector apparatus. Remote sites where U.S. groups are participating in research include: the Soudan Mine in Minnesota; the Sudbury Mine in Ontario, Canada; the Kamiokande Mine in Japan; Daya Bay in China; the Whipple Observatory in Arizona; the Pierre Auger Observatory in Argentina; the Cerro-Tololo Inter-American Observatory (CTIO) in Chile; the Apache Point observatory in New Mexico; the Waste Isolation Pilot Project (WIPP) in Carlsbad, New Mexico; the Boulby Mine in the United Kingdom (UK); and the Gran Sasso Underground Laboratory in Italy. Other research supported includes space-based projects such as participation in NASA's Gamma-ray Large Area Space Telescope (GLAST) mission, a DOE and NASA Joint Dark Energy Mission (JDEM) space-based satellite, and the Alpha Magnetic Spectrometer (AMS) led by the Massachusetts Institute of Technology.

Highlights

Recent accomplishments include:

- The Large Area Telescope (LAT), a DOE and NASA partnership and the primary instrument on NASA's GLAST mission, was tested and integrated into its launch vehicle in 2007 and is scheduled for launch from Kennedy Space Center in mid-2008. It will begin full operations late in 2008 and continue taking data for at least five years. SLAC led the DOE participation in the fabrication of the LAT and will run the instrument science operations center during the data-taking phase.
- First light from the Very Energetic Radiation Imaging Telescope Array System (VERITAS) was observed in 2007, with the telescope installed at the Whipple Observatory in Arizona. This facility is now one of the world's leading ground-based gamma-ray observatories.
- The Pierre Auger cosmic ray detector array in Argentina, a collaboration with the NSF and international partners, completed fabrication of its full array in 2007 and is now in full scale operations. The array covers an area of 3,000 square kilometers and is the largest of its kind in the world. Its purpose is to observe and study the very highest energy cosmic rays in the universe. The Auger experiment announced in November 2007 a major step forward in solving the long-standing mystery of the nature and origin of the highest energy cosmic rays: the collaboration traced the sources of the highest energy cosmic rays to the locations of nearby galaxies that have active galactic nuclei in their centers.

The major planned efforts in FY 2009 are:

- *Operation of the Large Area Telescope,* the primary instrument on NASA's GLAST mission. The goals of the LAT are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including active galactic nuclei and gamma ray bursts, as well as to search for dark matter candidates. It is complementary to the ground-based VERITAS experiment, which samples a higher energy region of the gamma ray spectrum. This research program is being carried out by a collaboration, which includes particle physicists and astrophysicists from SLAC, NASA research centers, the NRL, U.S. universities, and institutions in Italy, France, Japan, and Sweden.
- *Operations of the VERITAS Telescope Array*. VERITAS is a 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 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.

- *Fabrication of the Dark Energy Survey (DES) Project.* This Major Item of Equipment will provide the next step in determining the nature of dark energy, which is causing the universe to expand at an accelerating rate, by measuring the distances to approximately 300 million galaxies. DES employs several methods to measure the effects of dark energy on the distribution of these galaxies and other astrophysical objects. The DES scientific collaboration will build three systems which include the dark energy camera, the data management system and upgrades to the telescope facility. The camera is to be installed and operated on the Blanco 4 meter Telescope at the Cerro Tololo Inter-American Observatory (CTIO) in Chile. In FY 2009, $7,500,000 is requested to continue fabrication of the DES MIE. The project is a partnership between DOE and the NSF, which operates the telescope. The scientific collaboration is led by Fermilab and includes participants from laboratories and universities in the U.S., UK, and Spain.
- *Participation in a reactor neutrino experiment*. The FY 2009 request includes $13,000,000 for continued U.S. contributions for the fabrication of a Major Item of Equipment, a Reactor Neutrino Detector located in Daya Bay, China. This project is supported by a partnership between DOE and research institutes in China. This experiment will use anti-neutrinos produced from reactors to precisely measure a crucial parameter needed to pursue new physics opened up by the discovery of neutrino mass and mixing. The value and precision of this parameter will help resolve ambiguities in determinations of other neutrino properties, and will be a key input to determining the directions for further research in the neutrino sector.
- *Fabrication of the CDMS-25 Detector.* The Cryogenic Dark Matter Survey-25kg (CDMS-25) is a next-generation dark matter search experiment expected to increase sensitivity for direct detection of dark matter over current experiments by a factor of 10. It will use ultra-cold, super sensitive superconducting germanium detectors. The detectors will be manufactured at Stanford and tested at various U.S. institutions before being run in a refrigerated cryostat (designed and built by Fermilab) at SNOLab in Canada, one of the deepest underground laboratories in the world. This location will virtually eliminate cosmic ray backgrounds from the experiment and allow it to obtain its detection sensitivity. $500,000 is requested in FY 2009 to initiate fabrication of the CDMS-25 detector for deployment in the SNOLab underground facility, subject to successful peer review. This experiment was recommended by the Dark Matter Scientific Advisory Group and P5, but competes with other experiments of comparable sensitivity (using alternative technologies) for priority and funding.
- *R&D for future dark energy experiments*. In order to fully determine the nature of dark energy, the Dark Energy Task Force (DETF), a subpanel of both HEPAP and the Astronomy and Astrophysics Advisory Committee (AAAC) recommended a mix of experiments with independent and complementary measurements. The DETF report will be used to aid in the development of a coordinated dark energy research program containing specific experiments. The FY 2009 budget supports continued concept studies for JDEM, leading to a mission concept selection in 2009 and a planned FY 2010 fabrication start; and R&D for other near-term and next-generation ground- and space-based dark energy concepts.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
University Research	**18,703**	**18,960**	**19,749**

The university program consists of groups at more than 35 universities doing experiments at Non-Accelerator Physics facilities, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles and phenomena.

These university groups plan, build, execute, analyze, and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; develop new models and provide interpretations of existing experimental data; and train graduate students and postdoctoral researchers.

University physicists in this research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

In FY 2009, the university program in Non-Accelerator Physics will support research on several experiments including VERITAS, Pierre Auger, and GLAST/LAT which have completed their fabrication phase in recent years and are currently active in commissioning, operations, and/or data analysis. The detailed funding allocations will take into account the discovery potential of the proposed research. Other research efforts that will be continuing in this subprogram include: Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; CDMS-II dark matter search in the Soudan Mine in Minnesota; a direct search for axion dark matter particles (ADMX-I) at LLNL; and a 200 kg neutrinoless double beta decay experiment (EXO-200) at WIPP.

Continued R&D and design for a next-generation dark matter search experiment will take place, including extensions of the CDMS solid-state technology to larger detector sizes (greater than 25 kg), and alternative technologies based on noble liquid or gaseous detectors.

University groups are also participating in the design and R&D efforts for experiments in NSF's proposed Deep Underground Science and Engineering Laboratory, the Dark Energy Survey and the Reactor Neutrino Detector, as described above. Finally, R&D for a larger-scale (about 1,000 kg) neutrinoless double beta decay experiment will be supported. This experiment would measure the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle. University groups are leading these efforts.

National Laboratory Research	**31,466**	**33,107**	**33,883**

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

In FY 2009, the laboratory research program in Non-Accelerator Physics will continue to support research activities directed at fabrication of new detectors for dark energy and neutrino physics, including the Dark Energy Survey and the Reactor Neutrino Detector, and ongoing R&D of next-generation experiments, including a large-scale double beta decay experiment. The laboratory experimental physics research groups will be focused mainly on supporting the instrument science

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

operations center and data-taking and research for the GLAST/LAT telescope; operations and data analysis for the Pierre Auger cosmic ray detector array and the CDMS-II dark matter detector; operations of ADMX-I and EXO-200; R&D for ground- and space-based concepts for dark energy experiments; and analysis of data from Sloan Digital Sky Survey (SDSS) and the follow-on SDSS-II, which ends operation in 2008.

Projects	**8,796**	**20,837**	**32,230**

In FY 2009, this effort will be focused on R&D for the JDEM space-based dark energy mission concept and other potential dark energy experiments; and fabrication of three Major Items of Equipment (MIEs): the Dark Energy Survey (DES), the Reactor Neutrino Detector and CDMS-25 kg. In FY 2008, this budget category includes support for R&D to investigate a variety of methods and technologies for dark energy measurements using ground- and/or space-based facilities, to be selected using competitive peer review.

The FY 2009 JDEM R&D activities ($10,030,000) will focus on the conceptual design needed for a potential future space-based JDEM mission. A National Research Council's panel recommended in late 2007 that JDEM be the first of NASA's five Beyond Einstein program missions to be developed and launched. DOE and NASA are moving forward jointly on JDEM, and the selection of a specific concept for the JDEM mission is planned to take place in 2009. The selected concept would then begin the technical design phase, followed by fabrication and a launch near the middle of the next decade.

In their 2006 "roadmap" for high energy physics, the P5 prioritization subpanel of HEPAP recommended that DOE and NSF jointly pursue the DES project, a small-scale ground-based experiment that can provide significant advances in our knowledge of dark energy in the near term in a cost-effective manner. The FY 2009 request includes $1,200,000 for Other Project Costs, and $7,500,000 to continue fabrication of the DES MIE (preliminary DOE TPC $24,100,000–$26,700,000).

In FY 2009, $13,000,000 is provided to continue fabrication of the Reactor Neutrino Detector MIE (preliminary DOE TPC $32,000,000–$34,000,000[a]). This experiment will measure a crucial unknown neutrino property by precisely measuring the disappearance of electron antineutrinos generated by a nuclear reactor as they travel several hundred meters through the Earth to the underground detectors. In 2006, HEP, in cooperation with Chinese research institutes, decided to pursue this experiment at a site near the nuclear reactor facility in Daya Bay, China. The U.S. collaboration is led by groups from BNL and LBNL.

Funds are also requested to begin fabrication in FY 2009 of the CDMS-25 detector MIE (preliminary TPC $5,000,000–$7,000,000). The detector is planned to operate in the SNOLab underground facility.

[a] The estimated TPC for the Reactor Neutrino Detector has increased since the FY 2008 President's request budget, based on the results of project reviews and stretch out of the funding profile.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Other	**1,690**	**1,295**	**620**

This category includes funding mainly for non-accelerator-based research activities to be determined by peer review, and to respond to new and unexpected physics opportunities. It also includes funding for private institutions and other government laboratories and institutions that participate in Non-Accelerator Physics research, including support of the Smithsonian Institute for operations and research using the VERITAS telescope array.

Total, Non-Accelerator Physics	**60,655**	**74,199**	**86,482**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
University Research	
Funding for university-based research in this subprogram continues at approximately a constant level-of-effort to support research on several experiments which are currently active in commissioning, operations, and/or data analysis.	+789
National Laboratory Research	
Funding for laboratory-based research in this subprogram continues at slightly below a constant level-of-effort as some effort is redirected toward the fabrication of new projects.	+776
Projects	
Funding for Non-Accelerator Projects increases to reflect planned funding profiles for the Dark Energy Survey ($+3,200,000) and Reactor Neutrino Detector experiments ($+7,060,000), as these projects ramp-up fabrication efforts, the beginning of fabrication for the new 25-kg Cryogenic Dark Matter Survey MIE ($+500,000), and a ramp-up of JDEM R&D ($+4,773,000) during the final phase of the technology selection for the JDEM mission. These increases are partially offset by decreased R&D for possible other dark energy concepts ($-4,140,000) as the mission concept selection planned for 2009 focuses the near-term effort on JDEM.	+11,393
Other	
Funding for other non-accelerator-based activities is decreased, reflecting a shift of funds held for activities to be determined by peer review, and to respond to new and unexpected physics opportunities, into the general non-accelerator-based university and national laboratory research categories.	-675
Total Funding Change, Non-Accelerator Physics	**+12,283**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Theoretical Physics			
University Research	24,101	24,951	25,824
National Laboratory Research	24,075	24,271	25,724
SciDAC	5,870	5,248	5,600
Other	5,909	5,764	5,888
Total, Theoretical Physics	59,955	60,234	63,036

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.

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, and to illuminate the origin and evolution of the universe.

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

Research at Universities and National Laboratories

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

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

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

Highlights

Recent accomplishments include:

- High precision numerical simulations of the strong interactions of quarks and gluons, Quantum Chromodynamics (QCD), are producing accurate and reliable predictions of strong interaction decay constants and mass differences. These results, which use supercomputer simulations of QCD, include the important but difficult to calculate "virtual quark" effects in the underlying field theory. In some important cases, the agreement between the theoretical and experimental values has reached the level of the experimental uncertainty itself. This is a major success of the theory of strong interactions, and is an improvement by nearly an order of magnitude over previous calculations. These breakthroughs have been accomplished by the application of new, highly efficient algorithms combined with the use of today's supercomputers and dedicated clusters of personal computers.
- Recently, powerful new techniques derived from string theory have been developed to calculate high-energy strong interaction processes that will be measured at the LHC. These procedures came from the study of string theory. In traditional perturbative calculations, one calculates only one or two of the largest terms in an infinite series; but with the new approach, one can calculate an infinite set of terms, which will lead to more accurate predictions.
- Another recent development is the discovery of a correspondence between string theory in multi-dimensional space and conventional field theories in four dimensions. This insight enables completion of many previously intractable model calculations, which in turn illuminate physics related to quark-gluon plasmas and high energy scattering processes.

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 2009:

- *LHC Phenomenology.* As the start of LHC operations approaches, a greatly increased effort will be made to identify the most promising and sensitive methods for finding signs of new phenomena in the voluminous data that will be produced. Many attractive ideas have been proposed for the solution of fundamental problems such as the mysteries of the origin of the masses of the elementary particles and the mechanisms through which fundamental symmetries are broken in nature. Identifying which ideas are true will entail the calculation of detailed predictions of many suggested models for extensions of the Standard Model.
- *Lattice QCD*. QCD is a highly successful theory that describes the strong interactions between quarks and gluons. Although the equations that define this theory are in principle exact, none of the analytical methods that are so successful elsewhere in theoretical physics are adequate to analyze it. The reason that QCD is so intractable is that the coupling strength is near zero at very short distances but very strong at large distances (where "large" means the size of an atomic nucleus). The lack of

precision in current QCD calculations is now limiting the understanding of many experimental results. It has long been known that QCD can be analyzed to any desired precision by numerical methods, given enough computational power. Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made some QCD calculations feasible with quite high precision (one to two percent). Some of the computational software for this effort are provided through the SciDAC program.

- *New Ideas*. Theoretical physicists are speculating on whether there might be additional space dimensions that are normally hidden from us. These ideas are motivated by the effort to unify Einstein's theory of gravity with quantum mechanics in a mathematically consistent way. It is even possible that some of these dimensions and their consequences are accessible to experiment, perhaps manifesting themselves at the LHC in the production of mini-black holes, or so-called Kaluza-Klein excitations, named after the physicists who first suggested in the 1920's that we actually live in a 5-dimensional universe. Perhaps these ideas can explain the nature of dark matter, or dark energy, or even suggest new cosmologies explaining the history and evolution of the universe.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
University Research	**24,101**	**24,951**	**25,824**

The university program consists of groups at approximately 75 colleges and universities doing theoretical physics research. As part of their research efforts, the university groups train graduate students and postdoctoral researchers. University physicists in this theoretical research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

The theory program addresses problems across the full range of theoretical physics research. There is currently a "window of opportunity" to interpret and understand the exciting new physics results expected from the Fermilab Tevatron, currently searching for new physics at the energy frontier, and from the LHC, which will extend the energy frontier when it begins operations. The detailed funding allocations will take into account the involvement of university-based research groups in these targeted physics research activities.

In FY 2009, the university theory program is maintained at about a constant level-of-effort to support university research personnel participating in analysis of current and previous experiments, and in the design and optimization of new experiments, so that these experiments can fulfill their maximum potential.

National Laboratory Research	**24,075**	**24,271**	**25,724**

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

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

In FY 2009, the laboratory theoretical research groups will address problems across the full range of theoretical physics research, including the analysis and interpretation of the new data expected from the Tevatron Collider detectors, CDF and D-Zero, and preparation for the new higher energy data from the LHC. In FY 2009, actual funding for the laboratory theory program will be maintained at about a constant level-of-effort to support laboratory research personnel participating in analysis of current and previous experiments, and design and optimization of new experiments, so that these experiments can fulfill their potential to make new discoveries about the nature of the universe.

SciDAC	**5,870**	**5,248**	**5,600**

In FY 2009, HEP will continue support for successful proposals selected in the re-competition of the SciDAC program in FY 2006, and the separate accelerator simulation solicitation, awarded in FY 2007. Proposals are selected based on peer review. The SciDAC program is managed and cooperatively funded by the SC program offices, including the Advanced Scientific Computing Research program. The principal HEP-supported SciDAC efforts are in the areas of: Type Ia supernova simulations, to better understand the thermonuclear explosions that create supernovae, and to generate supernova light curves appropriate for dark energy measurements, a joint effort with Nuclear Physics (NP) and the National Nuclear Security Administration; platform-independent software to facilitate large-scale QCD calculations (see also Other below), a joint effort with NP; very large scale, fault-tolerant data handling and distributed "grid" computing that can respond to the serious data challenges posed by modern HEP and NP experiments, a joint effort with NP and the NSF; and large scale computational infrastructure for accelerator modeling and optimization, to support design and operations of complex accelerator systems throughout the SC complex, a joint effort with NP and the Basic Energy Sciences program.

Other	**5,909**	**5,764**	**5,888**

This activity includes funding for the Lattice QCD Computer Program, as well as for education and outreach activities, compilations of HEP data and reviews of data by the Particle Data Group at LBNL, conferences, studies, workshops, funding for theoretical physics research activities to be determined by peer review, and for responding to new and unexpected physics opportunities.

A coordinated effort with the NP and Advanced Scientific Computing Research programs is aimed toward the development of a multi-teraflops computer facility for Lattice QCD simulations. During FY 2006, a joint effort with NP to develop and operate a dedicated Lattice QCD facility with about 13 teraflop capacity was started, and in FY 2009 this program will proceed as planned.

In each year of the Lattice QCD investment, procurement of computers employing the most cost-effective option will be undertaken. Given current projections of price performance for this kind of high-performance computing, commodity clusters are the most effective investment. The HEP contribution of $1,200,000 to this effort in FY 2009 will correspond to about 2 teraflops of sustained computing performance, in addition to the computing power acquired in previous years.

This category also includes $750,000 for the QuarkNet education project in FY 2009. This project takes place in QuarkNet "centers" which are set up at universities and laboratories around the country. The purpose of each center is to allow students to understand and analyze real data from an active HEP experiment (such as the Tevatron or LHC experiments). Each center has 2 physicist mentors and, over a 3 year period, goes through several stages to a full operating mode with 12 high school teachers. The

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

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 was in place in FY 2004. Several centers have retired and new ones have started in the last few years. In FY 2009, most of the centers will be in stage 3, which is the full operations mode. QuarkNet operations will continue through the life of the LHC program at CERN.

	FY 2007	FY 2008	FY 2009
Total, Theoretical Physics	**59,955**	**60,234**	**63,036**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
University Research	
Funding for university-based research in this subprogram is maintained at approximately a constant level-of-effort.	+873
National Laboratory Research	
Funding for laboratory-based research in this subprogram is maintained at approximately a constant FY2008 level-of-effort.	+1,453
SciDAC	
Funding for the HEP-supported cooperative agreements under the SciDAC program is increased according to the planned funding profiles for those agreements.	+352
Other	
Funding for other theoretical physics research activities is approximately the same as FY 2008. Decreases due to the planned funding profile for the Lattice QCD hardware project ($-800,000), which is in its final year in FY 2009, are offset by an increase in funding held pending completion of peer review and/or programmatic decisions ($+924,000).	+124
Total Funding Change, Theoretical Physics	**+2,802**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Advanced Technology R&D			
Accelerator Science	36,619	37,208	47,229
Accelerator Development	98,556	44,859	95,638
Other Technology R&D	31,732	20,759	23,838
SBIR/STTR	—	17,653	20,388
Total, Advanced Technology R&D	166,907	120,479	187,093

Description

The mission of the Advanced Technology R&D subprogram is to foster world-leading research into the science of particle accelerators, as well as particle acceleration and detection techniques and instrumentation. These in turn provide enabling technologies and new research methods to advance scientific knowledge in a broad range of energy-related fields, including high energy physics, thereby advancing the DOE's strategic goals for science.

The Advanced Technology R&D subprogram provides the technologies and tools needed to design and build the accelerator and detector facilities needed to accomplish the programmatic mission. This is accomplished by supporting proposal driven, peer reviewed research in the fundamental sciences underlying the technologies used for experimental HEP research. These efforts focus on developing new technologies to the point where they can be successfully incorporated into construction projects that will significantly extend the program's research capabilities.

The Advanced Technology R&D subprogram includes not only R&D to bring new accelerator and detector concepts to the stage where they can be considered for use in existing or new facilities, but also advancement of the basic sciences underlying the technology. Most of the technology applications developed for high energy physics that prove useful to other science programs and to industry, flow from the work carried out in this subprogram.

High energy physics research relies on the use of high energy particle beams provided by charged particle accelerators, storage rings, and their associated detectors. The instrumentation to carry out a forefront, successful research program requires specialized technology that is state-of-the-art. The R&D programs that support such technology development are typically high-risk and long-term, but they have a high payoff in fundamental scientific breakthroughs.

The DOE HEP program has supported a very successful program of technology R&D that has ensured the availability of the most technically advanced research facilities and a world-class U.S. HEP program. Since in many cases the same technologies find applications to synchrotron light sources, intense neutron sources, very short pulse, high brightness electron beams, and computational software for accelerator and charged particle beam optics design, they are also widely used in nuclear physics, materials science, chemistry, medicine, and industry. Particle accelerators in particular have migrated into general usage for medical therapy and diagnostics, for preparation of radionuclides used in medical treatment facilities, and for the electronics and food industries. They are also now finding defense and homeland security applications.

Accelerator Science

The Accelerator Science activity in this subprogram focuses on the science underlying the technologies used in particle accelerators and storage rings, and the fundamental physics of charged particle beams. 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 testing of advanced superconducting materials, and user facilities for general support of accelerator research, such as the Accelerator Test Facility (ATF) at BNL.

Accelerator Development

The task of reducing new concepts and technical approaches to the stage of proven engineering feasibility, so that they can be incorporated into existing or new facilities, is done under Accelerator Development. Included in this activity are superconducting RF infrastructure development, studies of very high intensity proton sources for potential application in neutrino physics research, and R&D relevant to the proposed International Linear Collider.

Other Technology R&D

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

Highlights

Recent accomplishments include:

- At LBNL, a laser-driven plasma wakefield experiment has successfully trapped a bunch of electrons in a plasma and accelerated them to energies of 1 GeV in a few millimeters. The process creates an electron bunch in which the distribution of individual electron energies is very narrow, within a few percent of the average energy of the bunch. This is an important step forward from the earlier experiments that produced bunches with 100% energy spread and is an essential step in developing a useful plasma-based accelerator.

The major Advanced Technology R&D efforts in FY 2009 are:

- *Accelerator Science.* A broad range of topics in Accelerator Science will continue to be pursued. At the same time, increased support will be provided for a few of the most promising advanced acceleration concepts in order to capitalize on past investments and develop more compact, less expensive options for future high-energy accelerators beyond the ILC. Such a strategy was suggested by the external HEP Advanced Accelerator R&D Program Review Committee in 2007. In particular, funding is requested to support a new Advanced Accelerator R&D test facility that can provide a testbed for advanced acceleration concepts, such as plasma wakefield acceleration, that will broadly benefit the accelerator science community.

- *Research and Development of Superconducting RF technology.* HEP and a broad spectrum of other SC programs need a rigorous research and development program to produce cost competitive and reliable superconducting RF components for possible future accelerators that serve the overall science mission. This program will require extensive testing capability in our national laboratories to stimulate and evaluate new techniques, to demonstrate the quality of commercial products and to acquire crucial information needed for process improvements and quality control.

- *International Linear Collider R&D.* A TeV scale linear electron-positron collider has been identified by the 2006 National Academies' "EPP2010" study as "the essential component of U.S. leadership in particle physics in the decades ahead." In FY 2009, the R&D and design activities addressing critical performance and cost issues will continue on an international basis. The ILC R&D program in FY 2009 supports an important U.S. role in a comprehensive and coordinated international R&D program, and lays groundwork for U.S. industry to compete successfully for major subsystem contracts, should the ILC be built. The work needed to maintain U.S. leadership in specific technical areas for which the U.S. has unique capabilities will be continued.

  The Department will continue consultations with our international partners, with a goal of establishing a set of international agreements for accelerator R&D, including elements of ILC R&D. The information provided through these international activities would inform future decisions on the construction of and U.S. participation in the proposed ILC. These initial agreements may eventually lead to multilateral agreements for siting and construction of the ILC, similar to the ITER Engineering Design Activities (EDA) agreement (http://www.iter.org/EDA.htm).

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Accelerator Science	**36,619**	**37,208**	**47,229**
▪ **University Research**	**10,223**	**10,940**	**11,840**

The FY 2009 budget will continue support for a broad university research program in advanced accelerator physics and related technologies. The research program will continue to pursue investigations of novel acceleration concepts, including the use of plasmas and lasers to accelerate charged particles; theoretical studies in advanced beam dynamics, including the study of non-linear optics and space-charge dominated beams; development of high-field superconducting magnets and materials; studies of accelerating gradient limits in both normal conducting and superconducting RF accelerators; development of advanced particle beam sources and instrumentation; and accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams.

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.

In FY 2009, funding for the university research program will increase somewhat above the FY 2008 level-of-effort to support additional researchers and infrastructure to make optimal use of the new laboratory-based facility for advanced accelerator R&D (see below).

▪ **National Laboratory Research**	**25,203**	**25,288**	**34,071**

There are areas of Accelerator Science research that require the more extensive or specialized research facilities located at DOE national laboratories. The FY 2009 budget includes MIE funds of $8,000,000 for beginning fabrication of an Advanced Accelerator R&D Test Facility (preliminary TPC $15,000,000—$19,000,000) at a national laboratory to advance one or more of the most promising advanced acceleration schemes to the next level of development.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

In addition, there is increased funding in support of general laboratory-based accelerator science research ($+783,000), reflecting an approximately constant level-of-effort with respect to the FY 2008 programmatic effort and costs in this category.

The Accelerator Science program at ANL explores advanced methods to accelerate charged particles with the goal of more efficient, compact, and inexpensive particle accelerators. Effort in FY 2009 will focus on the development of dielectric wake-field accelerating structures via theoretical, computer simulation, and experimental studies. Other activities include the development of materials for high gradient acceleration, photonic band-gap accelerating structures, high-power/high-brightness electron beams, and advanced beam diagnostics.

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 2009, 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.

In FY 2009, LBNL will conduct research in laser-driven plasma acceleration at the L'Oasis laboratory. R&D on muon ionization cooling and theoretical studies of alternative muon acceleration schemes will also be carried out.

At Fermilab, the FY 2009 budget will support experimental studies of electron beam physics in a high-brightness photo-injector, research on muon acceleration, and research by the Accelerator Physics Center in beam theory and accelerator simulation. R&D in support of the international muon cooling collaboration with Rutherford Appleton Laboratory in the UK will continue.

The advanced accelerator R&D program at SLAC in FY 2009 will continue to support R&D into advanced particle acceleration technologies, and work with BES on R&D for new experimental capabilities at SLAC that take advantage of the unique qualities of the Linac beam. R&D into ultra high-frequency microwave systems for accelerating charged particles will be focused on high field breakdown phenomena and new accelerating geometries that support very high gradients. Very advanced electron-positron collider concepts and theoretical studies in advanced beam dynamics methods and new computer computation and simulation codes will continue. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the Accelerator Science activity.

Also supported in FY 2009 are theoretical studies of space-charge dominated beams at PPPL. 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 High Energy Physics program review supported by well-qualified peers, publications in professional journals, and participation in conferences and workshops.

▪ **Other**	**1,193**	**980**	**1,318**

This subactivity includes funding for Accelerator Science at sites other than universities and national laboratories. These include interagency agreements with NRL and the National Institute of Standards and Technology (NIST) and funding of industrial grants. Also included is funding for Accelerator

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

Science activities that are awaiting approval pending the completion of peer review and program office detailed planning.

Accelerator Development	**98,556**	**44,859**	**95,638**
▪ **General Accelerator Development**	**32,190**	**24,620**	**35,638**

This research includes R&D to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities, used in upgrading existing facilities, or applied to the design of new facilities. The work is mostly done at Fermilab, LBNL, SLAC, and BNL, with supporting activities at Thomas Jefferson National Accelerator Facility, ANL, LLNL, and LANL. The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; beam dynamics, both linear and nonlinear; and development of large simulation programs.

The R&D program at Fermilab in FY 2009 will address a broad spectrum of technology needs for that facility, including advanced superconducting magnet R&D, R&D for a high-intensity neutrino beam facility, advanced beam instrumentation, and simulation codes to provide improved modeling of all aspects of accelerator operations. Among these topics, emphasis will be placed on developing very high intensity proton sources for neutrino physics research. In particular, funding in this category in FY 2009 increases to further promote this R&D effort.

The LBNL R&D supported in FY 2009 includes work on very high field superconducting magnets using niobium-tin and similar advanced superconductors, on advanced RF systems, laser manipulation and measurement of charged particle beams, and a broad program in instrumentation development, accelerator theory, and computation. The very successful industrially-based program managed by LBNL to develop advanced superconductors, particularly niobium-tin, for the very high field superconducting magnet R&D program will continue to be supported.

The FY 2009 program at SLAC encompasses high-powered RF systems, beam instrumentation, generic electron-positron collider R&D, and advanced beam dynamics and machine simulation code development. Simulation codes for modeling RF system components and high-powered microwave tubes will receive special R&D focus.

The R&D program at BNL includes work on superconducting magnet R&D and associated superconducting magnet materials measurement facility.

▪ **Superconducting RF R&D**	**24,680**	**5,405**	**25,000**

The FY 2008 Energy and Water Development and Related Agencies Appropriations Act resulted in sharply reduced funding for Superconducting RF (SRF). This request resumes support for infrastructure needed for the testing and development of high-gradient superconducting accelerating cavity and cryomodule prototypes. The testing facilities and prototypes will help enable a host of SRF-based next generation scientific and industrial facilities, and in particular will be a critical component for the next generation of accelerators across the Office of Science complex, not just those with HEP applications.

In FY 2009, this effort will provide funds for procurement of components and support equipment necessary to prototype multi-cavity cryomodules. This request also enables continued development of U.S. capability for testing individual bare cavities, dressed cavities with all power components

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

attached, and cryomodules. Fermilab is the lead U.S. laboratory coordinating the national R&D program in this area.

▪ **International Linear Collider R&D**	**41,686**	**14,834**	**35,000**

The ILC is considered by the world-wide high energy physics community as the successor facility to the LHC, and essential for advancing scientific progress at the Terascale. In FY 2007, the ILC international collaboration under the auspices of the International Linear Collider Steering Group, and the direction of the Global Design Effort (GDE), completed a detailed review of the R&D to be accomplished world wide, with milestones and priorities for that work.

The FY 2008 Energy and Water Development and Related Agencies Appropriations Act resulted in sharply reduced funding for ILC R&D. In response, the FY 2009 budget supports a U.S. ILC R&D program with reduced scope compared to FY 2007, but addressing priority areas identified by the global R&D plan, and focused on topics for which the U.S. has unique expertise. Accelerator efforts will be centered on R&D for systems associated with the generation and maintenance of very bright particle beams such as electron sources, damping rings, beam dynamics, and beam delivery. Support will also be provided for development and prototyping of high level RF equipment and development of components associated with the main linac, including ILC cryomodules.

Where appropriate, directed R&D aimed at cost reduction of present baseline systems and developing alternate low-risk components will be undertaken.

Other Technology R&D	**31,732**	**20,759**	**23,838**
▪ **Advanced Detector Research**	**1,000**	**1,000**	**1,455**

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. Final funding levels will depend on the number and quality of proposals received. This program complements the detector development programs of the national laboratories.

▪ **Detector Development**	**30,732**	**19,759**	**22,383**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories and about 40 universities to advance these technologies to a point where there is reasonable chance that an experiment can adopt the technology successfully. Current areas of investigation include R&D on detector technologies that could be used to pursue new opportunities in future colliders (such as the ILC), particle astrophysics, and neutrino physics. Funding for this effort reflects current plans for general detector development activities.

The FY 2009 request will maintain R&D efforts directed toward developing new detectors including much needed prototyping and in-beam studies. In particular, funding is increased to enable greater participation of university researchers in these efforts. A diverse program applicable to dark matter and dark energy studies, as well as accelerator-based programs will be continued, including efforts on particle flow calorimeters, very low-mass trackers, liquid noble gas detectors, transducer technology (e.g., advanced charged-coupled devices, silicon photomultipliers), and radiation

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

resistant, fast readout electronics. Prototype calorimeter tracking and muon detection systems will be studied in the Fermilab test beam, providing a major test of particle flow algorithms and detector construction techniques.

SBIR/STTR	**—**	**17,653**	**20,388**

The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) set-asides are mandated by Congress. The HEP program manages topics related to accelerator science and technology and two topics related to detector science and technology in the annual procurement solicitation. The contents of each topic are based on material provided in response to an annual HEP solicitation for suggestions from scientists and engineers in universities and DOE national laboratories working in support of the HEP Advanced Technology R&D programs. There is also coordination with the DOE Nuclear Physics and Fusion Energy Sciences programs concerning areas of mutual interest. The selection of the R&D topics to be included in the annual solicitation is treated as an important and 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 2007, $17,279,000 was transferred to the SBIR program and $2,073,000 was transferred to the STTR program. The FY 2008 and FY 2009 amounts shown are estimated requirements for the continuation of the SBIR and STTR program.

Total, Advanced Technology R&D	**166,907**	**120,479**	**187,093**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Accelerator Science	
▪ Funding for university-based research increases somewhat above the FY 2008 level-of-effort to support additional researchers and infrastructure to make optimal use of the new laboratory-based facility for advanced accelerator R&D.	+900
▪ Funding for laboratory-based research in this subprogram increases ($+8,000,000) to support a new Advanced Accelerator R&D test facility that can provide a testbed for advanced acceleration concepts such as plasma wakefield acceleration, that will broadly benefit the accelerator science community. In addition, there is increased funding in support of general laboratory-based accelerator science research ($+783,000), reflecting an approximately constant level-of-effort with respect to the FY 2008 programmatic effort and costs in this category.	+8,783
▪ Funding for other accelerator science research activities reflects a slight increase in funding held pending completion of peer review and/or programmatic decisions.	+338
Total, Accelerator Science	**+10,021**

	FY 2009 vs. FY 2008 ($000)
Accelerator Development	
▪ Funding for general accelerator development activities increases to further promote development of very high intensity proton sources for potential application in neutrino physics research.	+11,018
▪ Funding for superconducting RF development increases to support continued development of U.S. infrastructure and test capability for RF cavities and cryomodules. This capability is essential for continued progress on, and for a full range of future applications, and in particular will be a critical component for the next generation of HEP accelerators.	+19,595
▪ Funding for International Linear Collider R&D increases to support an ILC R&D program focused on a limited number of machine issues, high level RF development, and cryomodule prototyping. The U.S. ILC collaboration will focus its R&D efforts on accelerator issues for which the U.S. has unique expertise and on development of components associated with the main linac.	+20,166
Total, Accelerator Development	**+50,779**
Other Technology R&D	
▪ Funding for Advanced Detector R&D reflects the planned funding level for this competitive solicitation.	+455
▪ Funding for Detector Development is increased to enable greater participation of university researchers in these efforts.	+2,624
Total, Other Technology R&D	**+3,079**
SBIR/STTR	
▪ Funding for SBIR/STTR increases according to the prescribed percentage.	+2,735
Total Funding Change, Advanced Technology R&D	**+66,614**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
General Plant Projects	8,850	11,390	6,600
Accelerator Improvement Projects	9,300	4,300	3,000
Capital Equipment	42,619	43,300	68,220
Total, Capital Operating Expenses	60,769	58,990	77,820

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

(dollars in thousands)

	Total Project Cost (TPC)	Other Project Cost (OPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Completion Date
Large Hadron Collider–CMS Detector, CERN	147,050[a]	75,261	71,789	70,539	1,250	—	—	FY 2007
Reactor Neutrino Detector, Daya Bay, China	32,000-34,000[b]	TBD	TBD	—	500	3,960	13,000	FY 2012
NuMI Off-axis Neutrino Appearance (NOνA) Detector, Fermilab	270,000[c]	TBD	TBD	—	1,000	—	7,000	FY 2014
Dark Energy Survey, Cerro-Tololo Inter-American Observatory, Chile	24,100-26,700[d]	TBD	TBD	—	—	3,610	7,500	FY 2011
Main Injector Experiment ν–A (MINERνA), Fermilab	16,800	6,100	10,700	—	—	5,000	4,900	FY 2010
Tokai-to-Kamioka (T2K) Near Detector, Tokai, Japan	4,680	1,700	2,980	—	—	1,980	1,000	FY 2009

[a] The total U.S. contribution (TPC) for this project is $167,250,000, including $20,200,000 from NSF.
[b] The estimated TPC for the Reactor Neutrino Detector has increased since the FY 2008 President's budget request, based on the results of project reviews and stretch out of the funding profile. CD-1 was approved in September 2007 with a preliminary TPC range of $32,000,000–$34,000,000. The TPC/TEC/OPC will be baselined at CD-2, planned for early 2008.
[c] TPC shown is an estimate. CD-1 was approved in May 2007 with a preliminary TPC range of $244,000,000–$293,000,000. CD-2 was planned for January 2008, but funding for FY 2008 was suspended by Congress and CD-2 will be rescheduled for early 2008 while this change is accommodated in the planning.
[d] The estimated TPC for the Dark Energy Survey has increased since the FY 2008 President's budget request which was based on CD-0, approved in November 2005 with a TPC range of $16,000,000–$20,000,000. CD-1 approval was granted in October 2007 with a preliminary TPC range of $24,100,000–$26,700,000 reflecting successful review of the Conceptual Design Report in May 2007.

	(dollars in thousands)							
	Total Project Cost (TPC)	Other Project Cost (OPC)	Total Estimated Cost (TEC)	Prior Year Appro- priations	FY 2007	FY 2008	FY 2009	Completion Date
CDMS-25 kg Detector, SNOLab, Canada	5,000-7,000[a]	TBD	TBD	—	—	—	500	FY 2012
Advanced Accelerator R&D test facility, TBD	15,000-19,000[b]	TBD	TBD	—	—	—	8,000	FY 2013
Total, Major Items of Equipment					2,750	14,550	41,900	

[a] The TPC is preliminary and CD-0 was approved in November 2007.
[b] The TPC is preliminary and CD-0 is planned for early 2008.

Nuclear Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Nuclear Physics					
Medium Energy Nuclear Physics	109,052	113,327	-938[a]	112,389	121,046
Heavy Ion Nuclear Physics	179,900	186,012	-829[a]	185,183	201,557
Low Energy Nuclear Physics	78,053	84,705	-1,120[a]	83,585	96,562
Nuclear Theory	33,205	34,956	-926[a]	34,030	39,954
Isotope Production and Applications[b]	—	—	—	—	19,900
Subtotal, Nuclear Physics	400,210	419,000	-3,813[a]	415,187	479,019
Construction	12,120	17,700	-161[a]	17,539	31,061
Total, Nuclear Physics	412,330[c]	436,700	-3,974[a]	432,726	510,080

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 101–101, "1989 Energy and Water Development Appropriations Act" (Established the Isotope Production and Distribution Program Fund)
Public Law 103–316, "1995 Energy and Water Development Appropriations Act" (Amendment to the Isotope Production and Distribution Program Fund to provide flexibility in pricing without regard to full-cost recovery)
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"

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 to develop the scientific knowledge, technologies and trained workforce that will be 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.

Description

Nuclear science began by studying the structure and properties of atomic nuclei as assemblages of protons and neutrons. Research focused on nuclear reactions, the nature of radioactivity, and the synthesis of new isotopes and new elements heavier than uranium. Significant benefits, especially to

[a] Reflects a reduction for the 0.91% rescission in P.L. 110-161, the Energy and Water Development and Related Agencies Appropriation Act, 2008.
[b] The Isotope Production and Applications program is transferred to the Office of Science from the Office of Nuclear Energy starting in FY 2009.
[c] Total is reduced by $10,436,000: $9,318,000 of which was transferred to the Small Business Innovative Research (SBIR) program and $1,118,000 of which was transferred to the Small Business Technology Transfer (STTR) program.

medicine, emerged from these basic research efforts. Today, the reach of nuclear science extends from the quarks and gluons that form the substructure of protons and neutrons, once viewed as elementary particles, to the most dramatic of cosmic events—supernovae. At its heart, nuclear physics attempts to understand the composition, structure, and properties of atomic nuclei; however, the field is driven by the following broad nuclear science frontiers as identified by the scientific community in the NSAC LRP—*The Frontiers of Nuclear Science (2007)*. The Nuclear Physics program is central to the development of various technologies relevant to 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.

- *Quantum Chromodynamics: from the structure of hadrons to the phases of nuclear matter.* A fundamental quest of modern science is the exploration of matter in all its possible forms. Over the past century, as this quest has taken us further and further inward, scientists have discovered that all matter is composed of atoms; that each atom contains a tiny, ultra-dense core called the nucleus; that the nucleus is composed of particles called protons and neutrons (often referred to collectively as nucleons); and that these nucleons are members of a broader class of particles called hadrons, which are complex bound states of nearly massless quarks and massless gluons. The quest has even yielded a set of mathematical equations known as quantum chromodynamics (QCD), which gives us a theoretical framework for understanding how quarks, gluons, and all these hadrons behave.
- *Nuclei and Nuclear Astrophysics: from structure to exploding stars.* At the core of every atom is an ultra-dense kernel of matter called the atomic nucleus. Comprising some 99.9 percent of the atom's mass—the other 0.1 percent resides in the outer cloud of electrons—the nucleus is a tightly bound cluster of positively charged protons and electrically neutral neutrons, known generically as nucleons. The forces that bind these nucleons are immensely strong, which is why nuclear processes are able to release a prodigious amount of energy; witness the thermonuclear fusion reactions that power our Sun and most other stars in the universe. But the forces between the nucleons are also quite complex, which is why nuclear matter displays a remarkably diverse variety of phenomena.
- *Fundamental Symmetries and Neutrino: in search of the New Standard Model.* The quest to explain nature's fundamental interactions, and how they have shaped the evolution of the cosmos, is among the most compelling in modern science. A major triumph in that quest came in the latter part of the 20^{th} century with the development of the standard model—a comprehensive and detailed picture of the electroweak and strong interactions. Nuclear physicists have played a key role in that success, starting five decades ago with their observation of parity-violation in nuclear beta decay, and continuing to the present day with their increasingly precise experimental tests of the standard model's predictions. The model has survived these tests with remarkable resiliency—which is why it is now accepted as the fundamental framework for three of the four known forces of nature.

Starting in FY 2009, the Isotope Production and Applications subprogram is transferred to the Nuclear Physics Program. This subprogram, with its importance to applied programs including the medical uses of isotopes, is a substantial beneficiary of the basic research conducted within Nuclear Physics.

Strategic and GPRA Unit Program Goals

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

Strategic Theme 3, Scientific Discovery and Innovation

- Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.
- Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

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

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

Contribution to GPRA Unit Program Goal 3.1/2.47.00, Explore Nuclear Matter - from Quarks to Stars

The NP subprograms (Medium Energy, Heavy Ion, Low Energy, Nuclear Theory, and Isotope Production) contribute to this goal 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 NP program contributes by building and supporting world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda. Investments maintain and develop critical infrastructure for safe, forefront research at these facilities. Scientific discoveries at the frontiers of nuclear physics further the Nation's energy-related research capacity, which in turn, provides for the Nation's security, economic growth and opportunities, and improved quality of life. In developing strategies to pursue these research opportunities, the NP program has been guided by the Long Range Plan (LRP) reports prepared by its primary advisory panel, the Nuclear Science Advisory Committee (NSAC). The most recent NSAC LRP, *The Frontiers of Nuclear Science,* was developed and submitted in 2007.

The Medium Energy subprogram investigates the quark and gluon substructure inside the nucleon. Although protons and neutrons can be separately observed, their quark constituents cannot because they are permanently confined inside the nucleons. Measurements are carried out using electron beams with the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF or JLab) and using polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL), as well as at other facilities worldwide.

The Heavy Ion subprogram searches for and characterizes predicted novel forms of matter and other new phenomena that might occur in extremely hot, dense bulk nuclear matter. The quarks and gluons that compose each proton and neutron are normally confined within these nucleons. However, if nuclear matter is compressed and heated sufficiently, quarks should become deconfined: individual nucleons will melt into a hot, dense plasma of quarks and gluons. Such plasma is believed to have filled the universe about a millionth of a second after the "Big Bang." Measurements are carried out primarily using relativistic heavy ion collisions at RHIC. Important measurements will also be made at the Large Hadron Collider (LHC) at the European Organization for Nuclear Research (CERN). Participation in the heavy ion program at the LHC provides U.S. 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 Low Energy subprogram studies nuclei at the limits of stability, nuclear astrophysics reactions, the nature of neutrinos, and fundamental symmetry properties in nuclear systems. The coming decade in nuclear physics may reveal new nuclear phenomena and structure unlike anything known from the stable nuclei of the world around us. Nuclear physics research is essential if we are to solve important problems in astrophysics—the origin of the chemical elements, the behavior of neutron stars, the origin of the highest-energy cosmic rays, core-collapse supernovae and the associated neutrino physics, and galactic and extragalactic gamma-ray sources. Measurements of nuclear structure and nuclear reactions are carried out primarily at the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) and the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL). Neutrinos are elusive particles that permeate the universe and hardly interact with matter, yet are believed to play a key role in the explosion of stars. Recent experiments have shown that a neutrino oscillates among all of its three known types as it travels from its source—something that can only happen if neutrinos have tiny masses. Studies to better understand the properties of neutrinos, and in particular their masses, are primarily carried out with specialized detectors located deep underground or otherwise heavily shielded against background radiation. Measurements of symmetry properties, particularly of the neutron, are being developed by nuclear physicists at the Spallation Neutron Source (SNS) at ORNL. The following indicators establish specific long-term goals in Scientific Discovery that the NP program is committed to, and progress can be measured against:

- investigating new regions of nuclear structure, studying interactions in nuclear matter like those occurring in neutron stars, and determining the reactions that created the nuclei of the chemical elements inside stars and supernovae; and
- determining the fundamental properties of neutrinos and fundamental symmetries by using neutrinos from the sun and nuclear reactors and by using radioactive decay measurements.

The Nuclear Theory subprogram provides the theoretical underpinning needed to support the interpretation of a wide range of data obtained from all the other NP subprograms, with the ultimate aim of advancing knowledge and providing insights into the most promising avenues for future research. A major theme of this subprogram is an understanding of the mechanism of quark confinement and de-confinement—while it is expected to be explained by Quantum Chromodynamics (QCD), a quantitative description remains one of this subprogram's great intellectual challenges. New theoretical tools will be developed to describe nuclear many-body phenomena, with important applications to condensed matter and other areas of physics. Understanding what consequences neutrino mass has for nuclear astrophysics and for the current theory of elementary particles and forces is also of prime importance. Computing resources are being developed to tackle challenging calculations of sub-atomic structure, such as those of Lattice Gauge QCD.

The Nuclear Theory subprogram also supports an effort in nuclear data that collects, evaluates and disseminates nuclear physics data for basic nuclear research and for applied nuclear technologies. These extensive nuclear databases are a national resource consisting of carefully organized scientific information that has been gathered over 50 years of low-energy nuclear physics research worldwide.

The Low Energy and Theory subprograms support experimental, nuclear data, and theory R&D that is relevant to the implementation of advanced fuel cycles in nuclear reactors. NP will support these efforts in FY 2009 addressing scientific opportunities where there are basic research questions and where the expertise and capabilities in the NP program can be utilized to address the needs of DOE's Nuclear Energy program in developing the next generation of nuclear reactors. Among the opportunities of high priority and impact are the development of cross-section covariance data that will allow for the establishment of uncertainties in model calculations, the development of the research capabilities (techniques and instrumentation) for important cross section measurements that cannot now be done or done to the precision needed, and the development of more robust and fundamental theoretical approaches for modeling reactions. These activities are being coordinated with the DOE Nuclear Energy and DOE SC Advanced Scientific Computing Research (ASCR) programs.

The Isotope Production and Applications subprogram supports the research and development and production of radioisotopes and making them more readily available for domestic U.S. needs. Radioisotopes represent high-priority commodities that are essential for successful energy, medical and national security applications and outcomes. Historically, DOE R&D investment has fueled the development of new isotopes and applications, including heart imaging; cancer therapy; smoke detectors; neutron detectors; isotopic and explosive detection; oil exploration; industrial radiography; and tracers for climate change. With federal support over the last several decades, use of isotopes has reduced health care costs, improved the ability of physicians to diagnose illnesses and improved the quality of life for innumerable patients, and strengthened national security. Support will be provided for research activities associated with the development and production of commercially unavailable research isotopes, in response to the needs of the community and based upon peer review.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Strategic Goals 3.1, Scientific Breakthroughs, and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.47.00 Explore Nuclear Matter - from Quarks to Stars			
Nuclear Physics	412,330	432,726	510,080

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 3.1/2.47.00 – Explore Nuclear Matter, from Quarks to the Stars					
Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 12%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 13%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 6%, on average, of total scheduled operating time. [Met Goal]	Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 10.4%, on average, of total scheduled operating time. [Met Goal]	Achieve at least 80% average operation time of the scientific user facilities as a percentage of the total scheduled annual operating time.	Achieve at least 80% average operation time of the scientific user facilities as a percentage of the total scheduled annual operating time.
				Achieve within 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.	Achieve within 10% for both the cost-weighted mean percentage variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects.
Medium Energy Nuclear Physics					
As elements of the electron beam program, (a) collected first data with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) collected first data to map out the strange quark contribution to nucleon structure using the G0 detector, utilizing the high intensity polarized electron beam developed at TJNAF. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.83), Hall B (8.06), and Hall C (2.11), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (1.77), Hall B (9.9), and Hall C (1.9), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.49), Hall B (12.42), and Hall C (3.01) 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, Hall B, and Hall C at the Continuous Electron Beam Accelerator Facility. FY 2008 Baseline: Hall A: 4.0; Hall B: 20.0; and Hall C: 5.0.	Weighted average number (2ithin 20% of baseline estimate) of billions of events recorded by experiments in Hall A, Hall B, and Hall C at the Continuous Electron Beam Accelerator Facility. FY 2009 Baseline: Hall A: 3.7; Hall B: 18.7; and Hall C: 4.7.
			The Relativistic Heavy Ion Collider plans no proton running in FY 2007.	The Relativistic Heavy Ion Collider plans no significant proton running in FY 2008.	Weighted average number (within 30% of baseline estimate) of millions of proton collision events sampled by the PHENIX and recorded by the STAR detectors, respectively, at the Relativistic Heavy Ion Collider. FY 2009 Baseline: PHENIX sample=500,000; STAR recorded=50.

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
Heavy Ion Nuclear Physics					
Initiated first round of experiments with collisions with other ions to compare to results of gold-gold collisions. [Met Goal]	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (900) and recorded by the STAR (40) detectors, respectively, at the Relativistic Heavy Ion Collider. [Met Goal]	No Target. (The Relativistic Heavy Ion Collider did not operate in heavy ion mode during FY 2006)	Weighted average number (within 30% of baseline estimate) of millions of events sampled by PHENIX (5,100) and recorded by the STAR (86.6) detectors during the heavy ion run at the Relativistic Heavy Ion Collider. [Met Goal]	Weighted average number (within 30% of baseline estimate) of millions of heavy-ion collision events sampled by the PHENIX and recorded by the STAR detectors, respectively, at the Relativistic Heavy Ion Collider. FY 2008 Baseline: PHENIX sample=7,500; STAR recorded=60.	Weighted average number (within 30% of baseline estimate) of millions of heavy-ion collision events sampled by the PHENIX and recorded by the STAR detectors, respectively, at the Relativistic Heavy Ion Collider. FY 2009 Baseline: PHENIX sample=6,000; STAR recorded=0.
Low Energy Nuclear Physics					
	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (28.1) and Holifield Radioactive Ion Beam (3.76) facilities, respectively. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (24.6) and Holifield Radioactive Ion Beam (7.1) facilities. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (27.6) and Holifield Radioactive Ion Beam (7.1) facilities. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System and Holifield Radioactive Ion Beam facilities, respectively. FY 2008 Baseline: ATLAS-22; HRIBF-2.4.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System and Holifield Radioactive Ion Beam facilities, respectively. FY 2009 Baseline: ATLAS-23.2; HRIBF-2.3.

Means and Strategies

NP supports 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; and starting in FY 2009, is responsible for the production of stable and radioactive isotopes important for the Nation. The program builds, supports, and maintains 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.

Radioisotope production is of interest to several federal agencies, including the National Institute of Health (NIH) and the Office of Biological and Environmental Research (BER) in the DOE Office of Science. The NP program will closely coordinate the research and isotope production activities within the Radioisotopes Production subprogram with relevant federal agencies.

Scientists supported by NP collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the NP National User Facilities. The program also supports collaborative work at foreign accelerator facilities, as well as joint development of instrumentation. The program promotes the transfer of the results of its basic research to a broad set of technologies involving advanced materials, national defense, medicine, space science and exploration, advanced computing, and industrial processes. In particular, nuclear reaction data are an important resource for these programs. NP user facilities are utilized by other SC programs, other DOE Offices (e.g., National Nuclear Security Administration and Nuclear Energy), other Federal agencies (e.g., NSF, NASA, and Department of Defense), and industry to carry out their programs.

The program is also cognizant of opportunities identified 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 informed by the advice of the National Academies concerning the scientific opportunities with rare isotope beams in its report *Scientific Opportunities with a Rare-Isotope Facility in the United States (2007).*

Although the NP program will use various means and strategies to achieve its program goals, a variety of external factors may impact the ability to achieve these goals. External factors that affect the programs and performance include: changing mission needs as described by the DOE and SC mission statements and strategic plans; evolving scientific opportunities, which sometimes emerge in a way that revolutionizes disciplines; 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; unanticipated failures, for example, in critical components of scientific user facilities, that cannot be mitigated in a timely manner; and strategic and programmatic decisions made by other Federal agencies and by international entities.

Validation and Verification

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

Program Assessment Rating Tool (PART)

The Department has implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by the Office of Management and Budget (OMB) to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The NP program has incorporated feedback from OMB into the FY 2009 Budget Request and is taking the necessary steps to continue to improve performance.

In the FY 2005 PART assessment, OMB gave the NP program a rating of "Effective". OMB found the program's management to be excellent with a relatively transparent budget justification and a fully engaged advisory committee that produces fiscally responsible advice. The assessment found that NP has developed a limited number of adequate performance measures that are continued for FY 2009. 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. NSAC reviews the progress towards achieving the long-term performance measures every five years; the results of the most recent assessment started in 2007 will be completed in 2008. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has provided NP with three recommendations to further improve performance:

- Respond to the recommendations of recent advisory committee reports, including implementing a budget-constrained and phased plan for the future of its research facilities. NP responded by:
- Engaging its advisory committee in a manner that produces responsible strategic advice within realistic budget scenarios. DOE and NSF charged NSAC to develop a new LRP for nuclear science. The plan, The Frontiers of Nuclear Science (December 2007), outlines the options for research, instrumentation, and facility development at different constrained levels of funding. NSAC also delivered a report in FY 2007 that evaluated the options and made recommendations for a next generation facility for rare isotope beams that can be constructed for approximately half the cost of the originally envisioned one billion dollar facility. The FY 2009 NP budget request and 5-year plan have been developed utilizing the guidance of the recommendations of these recent NSAC reports.
- Continuing to use external expert assessments (Committee of Visitors [COV]) to review the quality, relevance, and performance of the program's research portfolio and grant management process. The most recent COV review was held on January 9-11, 2007.
- Engage the National Academies, including experts outside of nuclear physics, to study the scientific capabilities of a proposed rare isotope accelerator in an international context. NP responded by engaging the National Academies to study the scientific opportunities of a proposed rare isotope beam facility and has encouraged broad representation from the scientific community. The Academies report entitled *Scientific Opportunities with a Rare-Isotope Facility in the United States (2007)* is posted at http://www.sc.doe.gov/np/.
- Maximize operational efficiency of major experimental facilities in response to increasing power costs. NP responded by conducting a focused review on optimizing operational efficiency of its four National User Facilities in the summer of 2006 to maximize the utilization and efficiency of major experimental facilities to ensure that the Nation's Nuclear Physics program achieves maximum

results. This was in addition to annual science and technology reviews of each of its National User Facilities.

To improve public access to PART assessments and follow up actions, OMB has created the ExpectMore.gov website. Information concerning NP PART assessments and current follow up actions can be found by searching on "nuclear physics" at http://www.ExpectMore.gov.

Basic and Applied R&D Coordination

The NP program is requesting $6,603,000 to support basic research in the characterization of radioactive waste through the advanced fuel cycle activities. NP supported a small on-going effort in basic research in FY 2007 and FY 2008 important for the NP mission and relevant to the issues involved with radioactive waste and related advanced fuel cycles. The NP program areas are structured as scientific disciplines with goals to understand fundamental nuclear physics. FY 2009 funding, if appropriated, will support research projects in experimental nuclear physics, nuclear theory, and nuclear data to support advanced nuclear fuel cycles. Nuclear data efforts will lead to improvements in nuclear reaction cross sections to reduce uncertainties needed to calculate the transmutation behavior of actinide elements for proposed advanced fuel cycles. The experimental effort will use appropriate research facilities and associated instrumentation to produce new data and reduce measured uncertainties in existing nuclear data for essential long-lived nuclear isotopes.

Funding requested in the outyears will significantly expand research in areas relevant to advanced reactor fuel cycles. The data produced will be input to existing models, as well as new models that are under development, to allow predictions of basic quantities such as fission product yield distributions. The National Nuclear Data Center is well positioned to lead the national nuclear data effort in the evaluation of reaction cross sections and covariance matrix development. Experimentalists will use a variety of nuclear instrumentation, NP supported facilities, and facilities operated by other institutions to make measurements.

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Characterization of Radioactive Waste			
Low Energy Nuclear Physics	—	—	4,537
Nuclear Theory	200	200	2,066
Total, Basic and Applied R&D Coordination	200	200	6,603

Advisory and Consultative Activities

In FY 2009, the DOE Nuclear Physics program will provide about 90% of the federal support for fundamental nuclear physics research in the Nation. The NSF provides most of the remaining support. 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. NP develops its strategic plan for the field with input from the scientific community via the NSAC long-range plans, which serve as a framework for the coordinated advancement of the field for the coming decade. These plans are undertaken every five to six years to review the scientific opportunities in the field, perform retrospective assessments of the major accomplishments by the field, and set priorities for the future. The plan provides guidance and recommends priorities for new construction projects. For example, the

2002 Long Range identified a facility for rare isotope beams as the highest priority for new construction and recommended proceeding with the 12 GeV upgrade of CEBAF as soon as possible. In the FY 2009 budget request, construction funds are requested for the 12 GeV CEBAF Upgrade project, and funding to begin conceptual design activities is requested for a facility for rare isotope beams.

Guidance from the NSAC long-range plans is augmented by NSAC reviews of subfields. Priorities identified in NSAC reviews of the Medium Energy and Low Energy subprograms were important input for the programmatic decisions to terminate user facilities operations of the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory (LBNL) in FY 2004 and of the Bates Linear Accelerator Center at the Massachusetts Institute of Technology in FY 2005. NSAC guidance on scientific opportunities and priorities provided in reviews of neutron science, the Nuclear Theory subprogram and the Heavy Ion subprogram, along with guidance from the FY 2007 NP review of the Low Energy subprogram, is reflected in the programmatic decisions in the FY 2008 and FY 2009 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 reflected in the breadth of the NP program and in the ongoing budget requests. These decisions have been made to maximize the scientific impact, productivity, quality and cost-effectiveness of the program within the resources available.

In 2005, DOE and NSF requested that NSAC and the High Energy Physics Advisory Panel (HEPAP) jointly appoint a Neutrino Science Assessment Group (NuSAG) to assess and make recommendations concerning opportunities in neutrino science. NuSAG has responded with reports on these opportunities: experiments to search for neutrino-less double beta decay and hence discover if the neutrino is its own anti-particle, and determine or limit the neutrino mass; and the measurement of neutrino oscillation mixing parameters utilizing neutrinos produced by reactors and accelerators. In 2007, NuSAG provided its last report assessing the opportunities for long baseline accelerator experiments to probe non-conservation of CP (charge-parity symmetry) in the neutrino sector, in which the recommendations included that the U.S. proceed with a long baseline neutrino oscillation program and pursue R&D towards the development of an intense, conventional neutrino beam to support the experiment.

In 2006, NSAC appointed a Committee of Visitors (COV) to review NP management processes; the COV conducted its review and reported on its findings in early 2007. Recommendations included the generation of a common database of reviewers for university grants and a more extensive database of the information contained in the university grants to facilitate tracking of the overall health of the program, and the addition of needed personnel to NP.

In FY 2006, NP and NSF charged NSAC to develop a long-range plan for nuclear physics, and to appoint a task force to evaluate the scientific reach and technical options for a facility for rare isotope beams to inform the on-going planning process and define technical options for such a facility. The task force provided its findings in a report in the summer 2007. The NSAC long-range planning process resulted in a report, *The Frontiers of Nuclear Science,* detailing the vision for nuclear physics for the next ten years. Published NSAC reports can be found at http://www.sc.doe.gov/np/nsac/nsac.html. The National Academy of Sciences (NAS) was charged with carrying out an independent assessment of the importance of the science portfolio available to a next generation facility for rare isotope beams. The report, *Scientific Opportunities with a Rare Isotope Facility in the United States (2007)*, addresses the role of a U.S. world-class facility for rare isotope beams for the future of the U.S. and international nuclear physics.

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 PACs also provide recommendations for proposals to be approved, conditionally approved, deferred, or rejected.

In order to better coordinate interagency activities, NP continues to participate in the Interagency Working Group (IWG) that developed the *National Science and Technology Council (NSTC) Report: A 21st Century Frontier for Discovery: The Physics of the Universe—A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy*. NP is playing a leading role in two of the major scientific thrusts identified in this report: Origin of Heavy Elements and High Density and Temperature Physics. Funding in FY 2009 partially supports the thrust on the Origin of the Heavy Elements at existing low energy facilities and supports High Energy Density Nuclear Physics with heavy ions at RHIC and participation in the heavy ion program at the LHC, all in the context of the Nuclear Physics mission.

Facility 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 operations, performance, and scientific productivity of the facilities. The results of the reviews 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. NP also periodically conducts focused facility operations reviews to analyze all aspects of facility operations. During the summer of 2006, NP conducted a review focused on assessing the operating efficiency of NP accelerator facilities; all four facilities were reviewed simultaneously so that facility representatives could benefit from "lessons learned" at other facilities.

In addition, the NP program reviews proposed and ongoing instrumentation projects to assess project plans and performance. These reviews, conducted by international experts, focus on scientific merit, technical status and feasibility, cost and schedule, and effectiveness of management organizations. Such reviews are used to establish mission need, and to provide important input in establishing cost and schedule profiles necessary for budget formulation and execution, and on an annual basis, to assess project performance.

Research

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

Significant Program Shifts

Operations of the MIT/Bates Linear Accelerator Center were phased out and pre-D&D activities started in FY 2005. The final funding increment for transfer of ownership of the facility was provided in FY 2008, turning ownership of the facility over to MIT in FY 2009 in exchange for MIT assuming responsibility for all future D&D activities and liability for the facility.

Starting in FY 2009, there is a new subprogram within the Nuclear Physics program entitled Isotope Production and Applications, consisting of the transferred Medical Isotopes Infrastructure program contained in the Radiological Facilities program within the Office of Nuclear Energy, plus support for research isotope development and production. A major objective of this program is to improve the availability and reliability of research isotopes at predictable prices needed for medical, national security, and industrial applications. A portfolio of research isotopes will be established with guidance from scientific advisory committees, in consultation with all segments of the research community interested in using stable and radioactive isotopes.

Medium Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Medium Energy Nuclear Physics			
Research			
University Research	17,469	18,219	19,182
National Laboratory Research	16,218	15,585	18,081
Other Research[a]	702	5,431	5,936
Total, Research	34,389	39,235	43,199
Operations			
TJNAF Operations	72,663	71,154	77,847
Bates Facility	2,000	2,000	—
Total, Operations	74,663	73,154	77,847
Total, Medium Energy Nuclear Physics	109,052	112,389	121,046

Description

The Medium Energy Nuclear Physics subprogram supports fundamental research directed primarily at answering the overarching questions that define the first frontier identified by the nuclear science community—quantum chromodynamics:

What is the internal landscape of the nucleons?

What does QCD predict for the properties of strongly interacting matter?

What governs the transition of quarks and gluons into pions and nucleons?

What is the role of gluons and gluon self-interactions in nucleons and nuclei?

The subprogram also supports investigations into aspects of several of the overarching questions that define the second and third frontiers—nuclei and nuclear astrophysics, and fundamental symmetries and neutrinos:

What is the nature of nuclear force that binds protons and neutrons into stable nuclei?

and

Why is there now more visible matter that antimatter in the universe?

What are the unseen forces that were present at the dawn of the universe, but disappeared from view as it evolved?

[a] In FY 2007, $3,584,000 was transferred to the SBIR program and $1,118,000 was transferred to the STTR program. This activity includes $3,652,000 for SBIR and $1,126,000 for STTR in FY 2008 and $3,689,000 for SBIR and $1,250,000 for STTR in FY 2009.

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. For example, the laws of quantum physics require that the angular momenta of quarks and gluons add up to the proton's known spin (intrinsic angular momentum), but experimental data so far have only been able to determine that about 20% of the proton's spin comes from the quarks. Further measurements are needed to determine the contribution from the gluons and the internal orbital angular momenta.

To achieve an experimental description of the nucleon's substructure, the Medium Energy subprogram supports different experimental approaches that focus on determining: the distribution of up, down, and strange quarks in the nucleons, the roles of the gluons that bind the quarks and 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), the effects of the quark and gluon spins within the nucleon, and the effect of the nuclear environment on the quarks and gluons; 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, CEBAF, as well as a major research effort at RHIC. Individual experiments are supported at the High Intensity Gamma Source (HIGS) at Triangle University Nuclear Laboratory, Fermi National Accelerator 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. CEBAF annually serves a nationwide community of about 800 DOE and National Science Foundation (NSF) supported scientists and students from over 80 U.S. institutions and about 400 scientists and students from 19 foreign countries. The NSF and foreign collaborators have made significant investments in experimental equipment. Allocation of beam time at CEBAF has been based on guidance from a Program Advisory Committee that reviews and evaluates proposed experiments regarding their merit and scientific priority.

FY 2007 Research 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. Recent Medium Energy subprogram developments include:

- Studies of the excited states of the proton using the CEBAF Large Acceptance Spectrometer (CLAS) detector at CEBAF are providing new information on what is believed to be a radial excitation of the quarks having the same quantum numbers as the ground state proton. These data reveal distinct roles of the virtual quarks and the valence quarks in the excited states.
- Recent unparalleled high precision measurements of electron parity violation scattering from the proton and the ^{4}He nucleus at CEBAF have constrained the magnitude of the contributions of strange quarks to be less than 3% of the charge radius and less than 9% of the magnetization of the proton. These results have also been used to improve by a factor of two existing limits on new physics beyond the Standard Model previously set by atomic parity violation experiments.
- The first statistically significant measurements using polarized protons at RHIC indicate that the contribution of the gluons to the proton's spin is consistent with zero but do not exclude a possible

negative contribution. The data also have provided the first determinations of parton spin–orbit correlations. These results fulfill one of the subprogram's science milestones for FY 2008.

- The MiniBooNE neutrino oscillation experiment (Fermilab) has announced its initial result that excludes the existence of a possible sterile neutrino that was implied from the results of the earlier Liquid Scintillator Neutrino Detector (LSND) experiment. These data are important for further constraining the possible mass hierarchies of the neutrino family.
- The TRIUMF Weak Interaction Symmetry Test Detector (TWIST) experiment at TRIUMF in Canada has published results of precision measurements of the muon decay parameters to test the parity-violating nature of the weak interaction. The results are consistent with the Standard Model.
- The MuCAP experiment at the Paul Scherrer Institute (PSI) in Switzerland has successfully completed a precision measurement of muon capture by the proton that will resolve an inconsistency of our understanding of the weak interaction in nuclei.

FY 2007 Facility and Technical Accomplishments

- TJNAF staff has developed a novel solution to the problem of higher order frequency modes in superconducting cavities that limits high power operations. The modified design allows heat generated in the coupler to flow away from the accelerator cavity, using a superconducting niobium RF probe that is kept thermally anchored via a single-crystal sapphire dielectric that is brazed between the niobium probe and an externally accessible copper collar.
- TJNAF has built a high resolution gamma camera ideally suited for small animal Single Photon Emission Computed Tomography (SPECT) with x-ray computed tomography (CT) capability. Tracking of an awake mouse's head is done through the use of infrared (IR) reflectors attached to the mouse's head. This technique may help researchers study human physiology and disease processes.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Research	**34,389**	**39,235**	**43,199**
▪ **University Research**	**17,469**	**18,219**	**19,182**

These activities comprise a broad program of research, and include support of about 180 scientists and 150 graduate students at 38 universities in 22 states and the District of Columbia. The research efforts utilize not only the accelerator facilities supported under the Medium Energy subprogram, but also other U.S. and foreign accelerator laboratories. Support funds personnel at levels needed to support the national Nuclear Physics program.

Support is provided for university researchers and groups to effectively carry out the CEBAF and RHIC research programs. Of this amount, $2,000,000 supports the MIT Research and Engineering (R&E) Center that is an integral component of MIT's medium energy research effort and utilizes the infrastructure remaining at the MIT/Bates facility for fabrication of instrumentation. University efforts at TJNAF are largely focused on studies of nucleon structure and its internal dynamics. In FY 2009, these include research efforts on 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; and photoproduction from a polarized target using the

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

CLAS detector. Efforts at RHIC will continue running of the 200 GeV spin program in preparation for a transition to the 500 GeV spin program.

▪ **National Laboratory Research**	**16,218**	**15,585**	**18,081**

Support for experimental groups at TJNAF restores CEBAF efforts at the level needed to effectively carry out the research program at the facility. Research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories not associated with TJNAF are supported at levels that will allow these groups to achieve their planned NP goals. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research efforts in Medium Energy Physics. In FY 2006, the reviewers evaluated each laboratory research group based on the significance of their accomplishments and future four-year program, the scientific leadership, creativity, and productivity of the personnel, and the overall cost-effectiveness of the group, which included support by the respective laboratory. Any issues associated with a group were identified. Each group was evaluated individually and then comparatively ranked. The highest performers received requested increases, where merited, and based on budgetary constraints. Low performing groups received recommendations to address issues identified in the review before any funding increases or decreases would be made, depending on their response to the recommendations.

• **TJNAF Research**	**6,254**	**6,391**	**7,220**

Scientists at TJNAF, with support of the user community, assembled the large and complex experimental detectors for Halls A, B, and C. TJNAF scientists provide necessary experimental support and operation of the detectors for safe and effective utilization by the user community. TJNAF scientists play a lead role in the laboratory's research program and their level of effort is increased in FY 2009 to support additional scientists for the development of the 12 GeV scientific program.

• **Other National Laboratory Research**	**9,964**	**9,194**	**10,861**

Support for national laboratory research activities at accelerator and non-accelerator facilities reflects the planned phase-out of the Laser Electron Gamma Source (LEGS) group at BNL while maintaining other laboratory research group efforts, 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 of which is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. ANL scientists have also successfully trapped radium, using their unique laser atom-trapping technique at ANL, which is a necessary step toward their goal to make a precision measurement of the atomic electric dipole moment that could shed light on the matter over antimatter excess in the universe.
- Support will be provided to the RHIC spin physics Medium Energy research groups at BNL and LANL. Both of these groups have important roles and responsibilities in the RHIC spin physics program.

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

- ► The LEGS experiment at BNL was completed in 2006. The polarized target technology along with the necessary staff has been transferred to TJNAF for use in the CEBAF Large Acceptance Spectrometer (CLAS) program. Support is provided to complete analysis of data taken in 2006.
- ► At LANL, support is provided to allow scientists and collaborators to complete the MiniBooNE anti-neutrino analysis and develop a transition plan for future neutrino research. The level of support in FY 2009 is dependent on the result of the transition plan.

	FY 2007	FY 2008	FY 2009
▪ **Other Research**	**702**	**5,431**	**5,936**
• **SBIR/STTR and Other**	**702**	**5,431**	**5,686**

In FY 2007, $3,584,000 was transferred to the Small Business Innovation Research (SBIR) program and $1,118,000 was transferred to the Small Business Technology Transfer (STTR) program. This activity includes $3,652,000 for SBIR and $1,126,000 for STTR in FY 2008 and $3,689,000 for SBIR and $1,250,000 for STTR in FY 2009 as well as other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

	FY 2007	FY 2008	FY 2009
• **Accelerator R&D Research**	**—**	**—**	**250**

The Medium Energy Accelerator R&D Research at universities and laboratories will develop the knowledge, technologies and trained scientists to design and build the accelerator facilities needed to carry out a forefront experimental program and to accomplish its DOE programmatic mission in nuclear physics.

	FY 2007	FY 2008	FY 2009
Operations	**74,663**	**73,154**	**77,847**
▪ **TJNAF Operations**	**72,663**	**71,154**	**77,847**

Funding supports CEBAF operations and Experimental Support for an approximate 30-week, 3-Hall operations schedule, after some funds are redirected towards the 12 GeV CEBAF project.

	FY 2007	FY 2008	FY 2009
• **TJNAF Accelerator Operations**	**46,499**	**44,724**	**50,499**

CEBAF operations are supported for a 4,400 hour running schedule, a 26% increase from estimated running in FY 2008, increasing the utilization of the facility from 56% with the FY 2008 Appropriation to 74%. Support in FY 2008 did not permit adequate staging of experiments and preparations for the start of the 2009 operations run, which is anticipated to negatively impact levels of operation in FY 2009. Beams can be provided to all three of the experimental halls simultaneously. Support is also provided for accelerator improvement projects (AIP) and General Plant Project (GPP) infrastructure improvements ($2,200,000) and to maintain efforts in developing advances in superconducting radiofrequency technology ($1,584,000).

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

	FY 2007	FY 2008	FY 2009
CEBAF Hours of Operation with Beam			
Optimal Hours	5,400	5,600	5,980
Planned Operating Hours	4,985	3,500	4,400
Achieved Operating Hours	5,719	N/A	N/A
Unscheduled Downtime	5.4%	N/A	N/A
Number of Users[a]	800	1,200	1,280

With the FY 2007 Appropriated funding, CEBAF focused on experiments requiring very low beam energy, which are significantly cheaper than the higher energy runs and easy to produce, leading to a large number of operating hours in FY 2007.

Funding for R&D activities for the upgrade of CEBAF to 12 GeV is completed in 2008. Funds are requested to begin construction in the Construction section of this budget.

- **TJNAF Experimental Support** **26,164** **26,430** **27,348**

The FY 2009 request supports Experimental Support efforts at the level needed for a 30-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 2009 funds for capital equipment ($5,700,000) are used for assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, and C; spectrometer systems and the continuation of the fabrication of second generation experiments. The Q_{weak} detector system has been fabricated to perform a precision measurement of the weak charge of the proton. This support is necessary to implement high priority experiments in the current 6 GeV experimental program prior to the 12 GeV CEBAF Upgrade project installation.

- **Bates Facility** **2,000** **2,000** **—**

Guidance from the NSAC long-range plans is augmented by NSAC reviews of subfields. Priorities identified in NSAC review of the Medium Energy subprogram were important input for the programmatic decision to terminate user facilities operations of the Bates Linear Accelerator Center at the Massachusetts Institute of Technology in FY 2005. Pre-D&D activities were started in FY 2005. The final funding increment for transfer of ownership of the facility in the amount of $2,000,000 is provided in FY 2008 as part of the agreement that turns ownership of the facility

[a] Counting of users at the NP facilities has been improved to ensure consistent counting methodology from one facility to the next and to remove possible double counting. The more accurate count is reflected for FY 2008 and FY 2009.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
over to MIT in FY 2009 in exchange for MIT assuming responsibility for all future D&D activities and liability for the facility.			
Total, Medium Energy Nuclear Physics	**109,052**	**112,389**	**121,046**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Research	
▪ **University Research**	
FY 2009 funding increases to support the personnel of the national Nuclear Physics program.	+963
▪ **National Laboratory Research**	
FY 2009 funding increases to support the personnel of the national Nuclear Physics program.	+2,496
▪ **Other Research**	
• SBIR/STTR and Other: Increase supports SBIR/STTR at levels proportionate to research and development activities.	+255
• Accelerator R&D Research: Funds are provided for accelerator R&D to develop the knowledge, technologies and trained scientists needed to design and build the accelerator facilities in order to accomplish the programmatic mission in nuclear physics and of the Department.	+250
Total, Other Research	**+505**
Total, Research	**+3,964**
Operations	
▪ **TJNAF Operations**	
• **TJNAF Accelerator Operations**	
FY 2009 funding restores CEBAF to operating levels needed to carry out the highest priority experiments within the current CEBAF 6 GeV program. Support for R&D for the 12 GeV CEBAF Upgrade is reduced according to the planned profile as the project moves into final design, and funding is redirected towards the 12 GeV CEBAF Upgrade. With this support, operating hours are increased by 26% (+900 hours).	+5,775

	FY 2009 vs. FY 2008 ($000)
• **TJNAF Experimental Support**	
FY 2009 funding is increased compared to FY 2008, funding personnel at levels needed for CEBAF experimental support activities that will support the facility running schedule. Experimental capital equipment support is increased to carry out the highest priority experiments within the current CEBAF 6 GeV program.	+918
Total, TJNAF Operations	**+6,693**
▪ **Bates Facility**	
The final funding increment for D&D activities at MIT/Bates was provided in FY 2008.	-2,000
Total, Operations	**+4,693**
Total Funding Change, Medium Energy Nuclear Physics	**+8,657**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Heavy Ion Nuclear Physics			
Research			
University Research	12,998	13,149	14,644
National Laboratory Research	22,151	22,263	27,598
Other Research[a]	—	4,454	5,612
Total, Research	35,149	39,866	47,854
Operations			
RHIC Operations	135,468	136,034	148,859
Other Operations	9,283	9,283	4,844
Total, Operations	144,751	145,317	153,703
Total, Heavy Ion Nuclear Physics	179,900	185,183	201,557

Description

The Heavy Ion Nuclear Physics subprogram supports fundamental research directed primarily at answering the overarching questions that define the first frontier identified by the nuclear science community—quantum chromodynamics:

What are the phases of strongly interacting matter, and what roles do they play in the cosmos?

What is the internal landscape of the nucleons?

What does QCD predict for the properties of strongly interacting matter?

What governs the transition of quarks and gluons into pions and nucleons?

What is the role of gluons and gluon self-interactions in nucleons and nuclei?

What determines the key features of QCD, and what is their relation to the nature of gravity and spacetime?

The subprogram also supports investigations into aspects of several of the overarching questions that define the second and third frontiers—nuclei and nuclear astrophysics, and fundamental symmetries and neutrinos:

What is the nature of neutron stars and dense nuclear matter?

and

Why is there now more visible matter that antimatter in the universe?

[a] In FY 2007, $4,390,000 was transferred to the SBIR program. This activity includes $4,390,000 for SBIR in FY 2008 and $5,296,000 for SBIR in FY 2009.

Historically, the first major milestone in establishing the idea for the formation of heated nuclear matter was marked in 1984 when scientists working at the LBNL Bevalac accelerator found the first direct evidence that nuclear matter can be compressed to high temperature and density using accelerated heavy ion beams. This observation led to the studies of hot and extremely dense hadronic matter created in heavy ion collisions with gold beams at the BNL Alternating Gradient Synchrotron (AGS) in 1992 and at the CERN Super Proton Synchrotron (SPS) in 1994. These tiny “fireballs” equilibrated rapidly, suggesting that the right conditions should exist at even higher beam energies to create a new phase of metamorphosed matter called the quark-gluon plasma (QGP)—named in the popular press as the mini “Big Bang,” since this primordial form of matter is thought to have existed shortly after the birth of the universe.

A new program of research on hot nuclear matter began at the Relativistic Heavy Ion Collider (RHIC) at BNL in 2000 when the first collisions of counter-circulating gold nuclei were observed at beam energies ten times higher than those available at any other facility in the world. The RHIC facility presently puts heavy ion research at the energy frontier and is also the only facility in the world that provides collisions of polarized protons with polarized protons. This latter unique capability allows 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 NSF National Superconducting Cyclotron Laboratory 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 seven highly successful running periods: Run 1 in FY 2000 with gold beams; Run 2, in FY 2001-2002, with gold beams and commissioning of polarized protons; Run 3 in FY 2003, with deuteron-gold collisions and the first physics results with polarized proton collisions; Run 4 in FY 2004 with high luminosity gold beams and polarized protons; Run 5 in FY 2005 with high luminosity copper beams and polarized protons; Run 6 in FY 2006 devoted to high statistics polarized proton operations; and Run 7 in FY 2007 with gold beams. This facility is utilized by about 1,200 DOE, NSF, and foreign agency supported researchers.

The NSAC Subcommittee Review of Heavy Ion Nuclear Physics in 2004 found the long-term plans for expanding the scientific reach of the U.S. program 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 Large Hadron Collider (LHC), nearing full operation 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 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 2008-2009 timeframe.

FY 2007 Research Accomplishments

In the seventh running period in FY 2007, RHIC delivered high intensity beams of gold ions for important measurements.

The wealth of heavy ion data from the years of operation of the RHIC collider has appeared in over 185 scientific publications. The results are leading to a developing paradigm of the matter produced in highly energetic nucleus–nucleus collisions as a "perfect liquid" with minimum viscosity.

- First measurements have been made of the viscosity/entropy ratio of hot dense partonic matter. This ratio was found to be small by an observation of large energy loss and significant hydrodynamic flow of mesons containing a charm quark. Data suggest heavy quarks may diffuse readily in a strongly-interacting Quark Gluon Plasma (sQGP) medium with minimum viscosity.
- Recent results show the response of hot dense partonic matter to energy deposited by transiting quarks or gluons is in the emission of additional particles at larger angles with lower momenta more typical of the medium than of normal hadron jets in proton-proton collisions. This striking modification of particle production depends on the amount of partonic matter traversed but is nearly independent of the colliding system and energy.
- Researchers continue to observe that the anisotropic collective flow of hadrons scales with the quark content of the hadron, even for composite nuclei such as deuterons. Phi mesons, a particle resonance or extremely short-lived particle, have a very similar mass to protons, but follow the flow pattern of other hadrons with two quarks, while deuterons behave as other baryons. This observation provides further evidence that the flow is built up early in the collision, when the degrees of freedom of the matter are those of quarks and gluons.
- New results on the relative production of particles containing charm and beauty at RHIC energies substantiates the discovery, contrary to theoretical prediction, that heavy quarks lose energy much the same as light quarks do in the new state of matter created in relativistic heavy ion collisions at RHIC.
- Experimental observations indicate the possible discovery that a shock front (mach-cone) is created by energetic particles that traverse the new state of matter created in relativistic heavy ion collisions at RHIC. The three-particle correlation data indicate a cone-like emission pattern, rather than a deflected jet topology, redolent of shock waves or Cherenkov radiation. Such observations could help to constrain the value of the speed of sound or the dielectric constant of the plasma.

FY 2007 Facility and Technical Accomplishments

- RHIC successfully operated with gold beams with over 100 bunches circulating in each collider ring. A new integrated luminosity record of ~ 2.8 nb^{-1} at 100 GeV per nucleon beam energy was achieved. This record is twice the luminosity of the previous Gold beam Run 4 in 2004.
- The first successful test of stochastic cooling of high energy, bunched heavy ion beams was accomplished in one ring at RHIC by using state-of-the-art fiber optic technology for signal processing and powerful narrow-band beam kickers. Actual longitudinal cooling of a gold beam at RHIC has been observed.
- The STAR Forward Meson Spectrometer Upgrade, a hodoscope of approximately 1,000 lead glass cells, was completed, and will be used for a definitive search for the Colored Glass Condensate in d+ Au collisions in a future run.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Research	**35,149**	**39,866**	**47,854**
▪ **University Research**	**12,998**	**13,149**	**14,644**

Support is provided for the research of about 120 scientists and 90 graduate students at 27 universities in 21 states. Funding provides support for university researchers to conduct research efforts at RHIC and the continuation of a modest program at the LHC. Support restores the NP workforce to levels needed to support the national Nuclear Physics program.

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 implementing 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**	**22,151**	**22,263**	**27,598**

Support is restored for scientists at five national laboratories (BNL, LBNL, LANL, ORNL, and Lawrence Livermore National Laboratory [LLNL]). These scientists provide essential personnel for designing, fabricating, and operating the RHIC detectors; analyzing RHIC data and publishing scientific results; conducting R&D of innovative detector designs; integrating electronics designs for high bandwidth data acquisition systems and software technologies; designing, fabricating, and operating LHC detectors; and planning for future experiments. Also, BNL and LBNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research efforts in Heavy Ion Energy Physics. In FY 2004, the five laboratory groups were evaluated based on the significance of their accomplishments and future program, the scientific leadership, creativity and productivity of the personnel, and the overall cost-effectiveness of the group, which included support by the respective laboratory. The report findings included an adjectival rating for these criteria along with an indication of the relative ranking of a particular laboratory group compared to the other groups. In response to the review, out-year funding guidance was provided to each group based on performance and availability of funds. BNL/RHIC management responded to this review with the development of mid-term (10-year) strategic plans for the Heavy Ion and Spin physics programs.

• **BNL RHIC Research**	**10,322**	**9,538**	**12,126**

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 2009 budget request allows BNL scientists to continue to provide adequate maintenance and infrastructure support of the experiments and to effectively utilize the beam time for research and to train junior scientists. The PHENIX Silicon Vertex Tracker (VTX) MIE (TEC = $4,700,000), a

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

joint project with the Japanese, is continued in FY 2009 for planned completion in FY 2010. 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. Capital equipment funds support the continuing fabrication in FY 2009 of two MIE's initiated in FY 2008, the PHENIX Nose Cone Calorimeter (NCC) and the PHENIX Forward Vertex Detector (FVTX). These new detectors are important for both the heavy ion and spin programs and have international partners. The NCC (preliminary TEC $4,500,000 - $4,700,000) is a fine grained silicon-tungsten sampling calorimeter that will measure the production of heavy quarks in order to characterize the new states of matter created at RHIC. The FVTX (TEC ~ $4,900,000) will provide vertex tracking capabilities to PHENIX and adds two silicon endcaps to the ongoing PHENIX VTX upgrade MIE. The support for these MIE's was reduced in the FY 2008 Appropriation, stretching the project schedule out and increasing project risk. Studies directed at developing the scientific case for a potential electron-heavy ion collider facility are supported.

	FY 2007	FY 2008	FY 2009
• **Other National Laboratory Research**	**11,829**	**12,725**	**15,472**

Researchers at LANL, LBNL, LLNL, and ORNL provide unique expertise and facilities for RHIC and LHC detector upgrades and analyses of data. For example, at LBNL, the large scale computational system, Parallel Distributed Systems Facility (PDSF), is a major resource used for the analysis of RHIC and LHC data, in alliance with the National Energy Research Scientific Computing Center (NERSC), and at LLNL computing resources are made available for the PHENIX data analysis. Research efforts are maintained at a level needed to support the national Nuclear Physics program. Capital Equipment funding is provided to continue U.S. participation in the heavy ion program at the LHC according to planned profiles. The LHC Heavy Ion MIE (preliminary TPC $13,000,000-$16,000,000) is a joint project with France and Italy that adds a calorimeter to the CERN A Large Ion Collider Experiment (ALICE) to provide the capability to study jet physics.

	FY 2007	FY 2008	FY 2009
▪ **Other Research**	—	**4,454**	**5,612**
• **SBIR and Other**	—	**4,454**	**5,362**

In FY 2007, $4,390,000 was transferred to the Small Business Innovative Research (SBIR) program. This activity includes $4,390,000 for SBIR in FY 2008 and $5,296,000 for SBIR in FY 2009 as well as other established obligations that the Heavy Ion Nuclear Physics subprogram must meet.

	FY 2007	FY 2008	FY 2009
• **Accelerator R&D Research**	—	—	**250**

The Heavy Ion Accelerator R&D at universities and laboratories will develop the knowledge, technologies and trained scientists to design and build the accelerator facilities needed to carry out a forefront experimental program and to accomplish its DOE programmatic mission in nuclear physics.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Operations	**144,751**	**145,317**	**153,703**
▪ **RHIC Operations**	**135,468**	**136,034**	**148,859**

RHIC operations are supported for an estimated 25-week running schedule (76% utilization) in FY 2009 that greatly expands the opportunities to vary the initial conditions (parameters) for forming the observed new state of matter. Reduced support in the FY 2008 Appropriation impacts preparations for the start of the FY 2009 operations run, which is anticipated to negatively impact levels of operation in FY 2009. The implementation of EBIS and detector upgrades will allow the RHIC program to make incisive measurements leading to more definitive conclusions on the discovery of strongly interacting quark gluon matter—the "perfect liquid"—and to establish whether other phenomena, such as a "Color Glass Condensate" or Chiral Symmetry Restoration exist in nature.

• **RHIC Accelerator Operations**	**104,839**	**104,700**	**115,460**

Support is provided for the operation ($111,160,000), capital investments ($1,000,000), and improvement ($3,000,000) of the RHIC accelerator complex. This includes the Tandem (that will be replaced by the Electron Beam Ion Source, under construction), Booster, and AGS accelerators that together serve as the injector for RHIC. FY 2009 operating funding will support about 25 weeks (3,100 hours) of operations, a 6 week increase compared to the FY 2008 Appropriation. The initial survey work 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.

	FY 2007	FY 2008	FY 2009
RHIC Hours of Operation with Beam			
Optimal Hours	4,500	4,100	4,100
Planned Operating Hours	3,430	2,230	3,100
Achieved Operating Hours	2,006	N/A	N/A
Unscheduled Downtime	30.3%	N/A	N/A
Number of Users[a]	900	1,200	1,200

• **RHIC Experimental Support**	**30,629**	**31,334**	**33,399**

Support is provided for the operation, maintenance, improvement, and enhancement of the RHIC experimental complex, including detectors, experimental halls, computing center, and support for users. The RHIC detectors have reached their initial planned potential and about 1,200 scientists and students from 82 institutions and 19 countries will participate in the RHIC research program in FY 2009. Two detectors will operate in FY 2009: STAR and PHENIX. These detectors

[a] Counting of users at the NP facilities has been improved to ensure consistent counting methodology from one facility to the next and to remove possible double counting. The more accurate count is reflected for FY 2008 and FY 2009.

	FY 2007	FY 2008	FY 2009
provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. FY 2009 funding will support Experimental Support efforts at the level needed for an estimated 25-week running schedule and to pursue important detector R&D activities, essential for developing the future capabilities of the experimental program. Base capital equipment funding is increased relative to FY 2008 to provide the support for maintaining computing capabilities at the RHIC Computing Facility (RCF) and for instrumentation.			
▪ **Other Operations**	**9,283**	**9,283**	**4,844**
The Nuclear Physics program provides funding to BNL for minor new fabrications, needed laboratory equipment (including general purpose equipment (GPE)), and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of DOE-owned facilities and for meeting its requirement for safe and reliable facilities operation.			
Total, Heavy Ion Nuclear Physics	**179,900**	**185,183**	**201,557**

(dollars in thousands)

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Research	
▪ **University Research**	
The increase for University Research grants in FY 2009 restores support to a level needed to support the Nuclear Physics program. The major focus of research will be at the RHIC program with data taking with STAR and PHENIX. A modest effort is directed towards research at the LHC heavy ion program at CERN.	+1,495
▪ **National Laboratory Research**	
• BNL RHIC Research: The FY 2009 budget request restores support to a level needed to support the national Nuclear Physics program. Funding for capital equipment is provided to continue the fabrication of the PHENIX Vertex Tracker (VTX), the PHENIX Nose Cone Calorimeter (NCC) and the PHENIX Forward Vertex (FVTX) detector MIEs.	+2,588
• Other National Laboratory Research: The FY 2009 increase restores research efforts at a level needed to support the national Nuclear Physics program and provides funding for additional capital equipment investments, in particular an increase of $2,000,000 for the Electromagnetic Calorimeter upgrade to the LHC ALICE experiment. These funds will ensure that National Laboratory researchers continue to provide adequate support to the RHIC and LHC experiments and its upgrades, and to effectively utilize the beam time for research and to train students and young scientists.	+2,747
Total, National Laboratory Research	**+5,335**

	FY 2009 vs. FY 2008 ($000)
▪ **Other Research**	
• SBIR and Other: Increase reflects required SBIR obligations.	+908
• Accelerator R&D Research: Funds are provided for accelerator R&D to develop the knowledge, technologies and trained scientists needed to design and build accelerator facilities to accomplish its DOE programmatic mission in nuclear physics.	+250
Total, Other Research	**+1,158**
Total, Research	**+7,988**
Operations	
▪ **RHIC Operations**	
• RHIC Accelerator Operations: The FY 2009 request supports an approximate 25 week running schedule to meet the program's scientific goals and performance measures. An increase of $1,100,000 is provided for accelerator improvement projects (AIP) to impact operational efficiency and provide new capabilities. Capital Equipment is increased by $300,000 to restore to FY 2007 levels.	+10,760
• RHIC Experimental Support: Funding is provided for experimental scientific/technical staff and materials and supplies, and capital equipment that effectively support the maintenance and operation of the PHENIX and STAR detectors at RHIC for a 25-week operating schedule. Base capital equipment funding is increased by $500,000 compared to FY 2008.	+2,065
Total, RHIC Operations	**+12,825**
▪ **Other Operations**	
The FY 2009 general plant project (GPP) funds are reallocated to the Science Laboratory Infrastructure program in support of renovating the infrastructure across SC's laboratory complex to achieve SC's strategy for mission readiness. Support of general plant project activities will be accomplished using institutional general plant project funding.	-4,439
Total, Operations	**+8,386**
Total Funding Change, Heavy Ion Nuclear Physics	**+16,374**

Low Energy Nuclear Physics

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Low Energy Nuclear Physics			
Research			
University Research	18,787	19,621	20,440
National Laboratory Research	27,203	30,192	35,137
Other Research[a]	4,175	5,519	8,822
Total, Research	50,165	55,332	64,399
Operations	27,888	28,253	32,163
Total, Low Energy Nuclear Physics	78,053	83,585	96,562

Description

The Low Energy Nuclear Physics subprogram supports fundamental research directed primarily at answering the overarching questions that define the second and third frontiers identified by the nuclear science community—nuclei and nuclear astrophysics, and fundamental symmetries and neutrinos:

What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?

What is the origin of simple patterns in complex nuclei?

What is the nature of neutron stars and dense nuclear matter?

What is the origin of the elements in the cosmos?

What are the nuclear reactions that drive stars and stellar explosions?

and

What is the nature of the neutrinos, what are their masses, and how have they shaped the evolution of the universe?

Why is there now more visible matter than antimatter in the universe?

What are the unseen forces that are present at the dawn of the universe, but disappeared from view as it evolved?

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

[a] In FY 2007, $1,344,000 has been transferred to the SBIR program. This activity includes $1,344,000 for SBIR in FY 2008, and $1,426,000 for SBIR in FY 2009.

dripline, the structure of neutron-rich nuclei, and the surprising stability of rapidly spinning very heavy nuclei. Stable beams and the first radioactive beams in the mid-1990's enabled nuclear structure and cross-section experiments to determine the nuclear reaction paths and some rates for the breakout from the stellar carbon-nitrogen-oxygen (CNO) cycle that leads to production of heavier elements. In the 2000's the pace of nuclear physics experiments important for nuclear astrophysics has quickened. 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. New experimental programs are beginning to explore the *r*-process and *rp*-process pathways for nucleosynthesis. The HRIBF facility now produces over 150 proton-rich and neutron-rich radioactive beams for research. New radioactive beams are being developed to increase the scientific reach of the facility. The CAlifornium Rare Isotope Breeder Upgrade (CARIBU) is being developed at ATLAS to provide accelerated rare isotope beams that will complement the capabilities of HRIBF.

The National User Facilities, HRIBF and ATLAS, are utilized by DOE, NSF, and foreign-supported researchers. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation. Accelerator improvement project (AIP) funds are provided to improve the reliability and efficiency of operations, and to provide new accelerator capabilities. The LBNL 88-Inch is being supported to test electronic circuit components for radiation "hardness" to cosmic rays by the National Reconnaissance Office (NRO) and U.S. Air Force (USAF), and for a small in-house nuclear physics research program by the NP program. A Memorandum of Agreement between NP, NRO, and the USAF provides for joint support of the 88-Inch Cyclotron through 2011. In FY 2009, fabrication continues at LBNL for the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA) MIE, a segmented germanium detector array with improved position resolution and efficiency for studies with fast fragment nuclear beams.

Progress in both nuclear structure and nuclear astrophysics studies depends in part upon the availability of rare isotope beams to produce and characterize nuclei that lie in unstudied regions of the nuclear chart and that are involved in important astrophysics processes. While the U.S. today has facilities with capabilities for these studies, the Department has determined that a facility with next generation capabilities for short-lived radioactive beams will be needed for the U.S. to maintain a leadership role. A National Academy of Sciences (NAS) study provided an independent scientific assessment and concluded that "the science addressed by a rare isotope facility, most likely based on a heavy ion driver using a linear accelerator, should be a high priority for the United States" (*Scientific Opportunities with a Rare Isotope Facility in the United States* available at http://www.sc.doe.gov/np/). Guidance has been obtained from NSAC regarding the technical options for a U.S. world-class facility that complements capabilities available elsewhere in the world and that can be built with the resources available. The construction of a U.S. facility for rare isotope beams is a major recommendation of the 2007 NSAC Long Range Plan. A solicitation in FY 2008 will identify the most promising path forward and a site for the facility. In FY 2009, funding is requested to support rare isotope beam R&D and Conceptual Design activities.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations are supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL) at Duke University, and at Yale University; infrastructure is supported at the University of Washington to enable scientific instrumentation projects to be undertaken. Each of these university Centers of Excellence has a critical mass of nuclear physics faculty involved in research that is conducted both on and off campus and about 15-25 graduate students at different stages of their education. These students historically have been an important source of leaders in the field. Many of these scientists, after obtaining their Ph.D.s, contribute to a wide variety of nuclear technology programs of interest to the DOE and the Nation.

In neutrino physics, the Sudbury Neutrino Observatory (SNO) experiment was designed and built to search for neutrino flavor oscillations with solar neutrinos. It was spectacularly successful, showing that neutrinos produced in the core of the sun change their character (oscillate) as they traverse solar matter, and thus have mass. SNO concluded its data taking phase in FY 2007 and the collaboration continues data analysis and reporting in FY 2008 and FY 2009. SNO's results confirm that the sun indeed draws its energy from nuclear reactions and the number of neutrinos measured agrees well with solar neutrino emission calculated with current models of the sun. The KamLAND detector in Japan is continuing to study the properties of anti-neutrinos produced by nuclear power reactors, while entering a new experimental phase to measure lower energy solar neutrinos following an upgrade of the detector. Together, SNO and KamLAND, along with other neutrino oscillation experiments, have led to significant progress in understanding the nature of neutrinos. In FY 2008, a U.S. laboratory and university collaboration joined the Italian-lead Cyrogenic Underground Observatory for Rare Events (CUORE) experiment at the Gran Sasso Laboratory, contributing to the fabrication of the detector that is planned to become operational in approximately FY 2012. This experiment will search for evidence that the neutrino is its own antiparticle (a Majorana particle), and determine or set a limit on the effective Majorana mass of the neutrino. In FY 2007, a U.S. university collaboration began limited but crucial participation in the German-lead KArlsruhe TRitium Neutrino (KATRIN) experiment to determine kinematically the mass of the electron neutrino by measuring the beta decay spectrum of tritium. This experiment will become operational in approximately 2011.

The Low Energy subprogram also supports studies of fundamental interactions and symmetries in selected nuclei: "laboratories" that allow precise measurements to test the present understanding of the Standard Model. Some experiments use accelerators in conjunction with special apparatus to study fundamental nuclear and nucleon properties, such as reactions with and decays of cold neutrons. Such experiments are being mounted at cold and ultra-cold beam lines at the SNS, or are being prepared. In FY 2009, fabrication continues for the Fundamental Neutron Physics Beamline (FNPB) MIE at the SNS in preparation for these measurements of fundamental properties of the neutron including the electric dipole moment of the neutron (nEDM).

FY 2007 Research Accomplishments

The Low Energy subprogram has significant achievements in FY 2007 that are related to the central questions about nuclear structure, nuclear astrophysics, and fundamental interactions and symmetries. The basic knowledge and understanding in these areas have been further extended by these recent highlights:

- Evidence for neutron-proton pairing has been recently found in experiments at ATLAS at ANL. Starting with nuclei such as ^{66}As (N=Z=33) up to ^{86}Tc, a "pairing gap" appears in the low-lying level spectrum that is similar to the gaps found for even-even nuclei. These neutron-proton pairing correlations have been predicted to have a major impact on nuclear properties that influence the *rp*-process in nucleosynthesis in stars.
- The use of neutron-rich radioactive beams may enhance the production rate of heavy element synthesis. At HRIBF, the fusion of neutron-rich radioactive ^{132,134}Sn beams with ^{64}Ni has been compared with the fusion of stable $^{112\text{-}124}$Sn beams with the same target, measuring the yield of evaporation residues in each case. The yield for producing evaporation residues of the same mass is

higher in the reactions with more neutron-rich Sn beams. This suggests that neutron-rich radioactive beams could be effectively utilized to synthesize new neutron-rich isotopes of heavy elements.

- Certain atomic nuclei with special numbers of both protons and neutrons, referred to as "doubly-magic" nuclei, have unusually stable configurations, and serve as fundamental benchmarks in the development of the basic theory of nuclei. Some of these doubly-magic nuclei, such as ^{132}Sn, are unstable and can only be studied using radioactive beam techniques. At HRIBF, experiments have started using radioactive Sn nuclei to determine the properties of nuclei near ^{132}Sn. These experiments not only provide important information for the development of nuclear theory, but also data critical to understanding how the heavy elements are formed in stellar explosions.
- Understanding how simple and coherent collective motions arise from individual particles is an exciting challenge for all quantum systems, from the quark level to quantum dots. A breakthrough method using projectile Coulomb excitation experiments with ATLAS and Gammasphere at ANL has been used to selectively populate and identify for the first time a mixed symmetry state in ^{138}Ce. This technique opens the way to survey the development of neutron-proton collectivity across whole regions of nuclei.

FY 2007 Facility and Technical Accomplishments

- The Versatile ECR for NUclear Science (VENUS) electron-cyclotron resonance (ECR) ion source, developed at LBNL, is the first fully functional superconducting ECR ion source in operation with magnetic confinement fields strong enough for optimized operation at 28 GHz. Performance is a factor of 8 to 10 higher than reported for conventional ion sources, and makes possible the high beam powers at lower beam energy now being considered for a future U.S. facility for rare isotope beams.
- A high intensity gas catcher is a central component required to produce reaccelerated beams of radioactive nuclei at a future facility for rare isotope beams in the U.S. The performance of the gas catcher has been improved by a new design, which uses a radio-frequency structure that surrounds the ion cloud to selectively focus and guide radioactive ions to the extraction nozzle of the gas catcher. With this design, the bulk of the ionization density, mostly helium ions, is rapidly neutralized on the electrodes. The device was successfully operated with high efficiency at incident ion rates four orders of magnitude higher than previously demonstrated. These intensities meet the requirements for the proposed U.S. facility for rare isotope beams.
- The High Power Target Laboratory (HPTL) project was completed and commissioned at the HRIBF in FY 2006. The HPTL advances the state of the art of Isotope Separator On-Line (ISOL) radioactive ion beam production, including the development of targets, ion sources, and beam production and purification techniques. Currently, the HPTL is being utilized to develop a target and ion source for the production of radioactive aluminum beams that will enable studies of nuclear cross sections relevant to the interpretation of the aluminum gamma-ray distribution in the galaxy that is observed by orbiting observatories.
- The construction and commissioning of the High Intensity Gamma-ray Source (HIγS) at Duke University was completed in FY 2007. The (HIγS) facility will provide unique capabilities to use photonuclear interactions for studies of nucleon and nuclear structure, nuclear astrophysics, and nuclear applications.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Research	**50,165**	**55,332**	**64,399**
▪ **University Research**	**18,787**	**19,621**	**20,440**

Support is provided for the research of about 123 scientists and 97 graduate students at 35 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. Support restores the NP workforce to levels needed to support the national Nuclear Physics program.

FY 2009 funding for operation of university accelerator facilities and for researchers and students provides support at levels needed to support the national Nuclear Physics program. Capital equipment at the university accelerator facilities is modestly increased (+$105,000) relative to FY 2008 levels for investments in experimental instrumentation and enhanced capabilities.

- University researchers conduct programs using the low energy heavy ion beams and specialized instrumentation at the ATLAS and HRIBF National User Facilities. These efforts at the user facilities involve about two-thirds of the university scientists supported by this subprogram.
- Accelerator operations are supported for in-house research programs at the TUNL facility at Duke University, TAMU, and Yale University. These small university facilities have well-defined and unique physics programs, providing photons, neutrons, light ion beams, or heavy ion beams, specialized instrumentation, and opportunities for long-term measurements that complement the capabilities of the national laboratory user facilities. Modest equipment funds are provided for new instruments and capabilities.
- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements are supported, such as measurements and analyses of data for solar and reactor neutrino rates and the neutrino mass at SNO, KamLAND (jointly with the High Energy Physics program), and Karlsruhe Tritium Neutrino (KATRIN), and development of the fundamental neutron program at the SNS with the Fundamental Neutron Physics Beamline.

▪ **National Laboratory Research**	**27,203**	**30,192**	**35,137**

Support is provided for the research programs of scientists at six national laboratories (ANL, BNL, LBNL, LANL, LLNL, and ORNL). Support restores the NP workforce to levels needed to support the national Nuclear Physics program. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research efforts in the Low Energy Nuclear Physics sub-program. In FY 2007, the reviewers evaluated each laboratory research group based on the significance of their accomplishments and future program, the scientific leadership, creativity and productivity of the personnel, and the overall cost-effectiveness of the group, which included support by the respective laboratory. Any issues associated with a group were identified. Each group was evaluated individually and then comparatively ranked. The highest performers received increases where merited and based on budgetary constraints. Low performing groups received

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

recommendations to address issues identified in the review before any funding increases or decreases would be made, depending on their response to the recommendations.

	FY 2007	FY 2008	FY 2009
• **National Laboratory User Facility Research**	**10,540**	**11,016**	**12,040**

Scientists at ANL and ORNL have major responsibilities for maintaining, improving, and developing instrumentation for research by the user communities at the ATLAS and HRIBF National User Facilities, as well as playing important roles in carrying out research that addresses the NP program's priorities. In FY 2009, funding for ANL and ORNL research at the user facilities is provided to restore to levels needed to support the national Nuclear Physics program for nuclear structure and astrophysics research with emphasis on high priority projects. Support is provided for the following research activities.

- ► At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS coupled to ion traps; Gammasphere and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei; and the study of nuclei at the extremes of excitation energy, angular momentum, deformation, and isotope stability. Studies are undertaken with the Advanced Penning Trap to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model.
- ► 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 beta-delayed neutron branching ratios, 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.

	FY 2007	FY 2008	FY 2009
• **Other National Laboratory Research**	**16,663**	**19,176**	**23,097**

Scientists at BNL, LBNL, LLNL, LANL, and ORNL play important roles in several high-priority accelerator- and non-accelerator-based experiments (e.g.; SNO, KamLAND, nEDM and CUORE) directed toward fundamental questions. Double Beta Decay (DBD) experiments, such as CUORE, will search for the neutrino-less double beta decay mode, to measure, or determine an upper limit for, the absolute mass of the neutrino and determine whether the neutrino is its own antiparticle. R&D activities are supported for another neutrino-less DBD experiment, based on a different technology.

Capital equipment funding is provided to support the ongoing GRETINA, FNPB, CUORE and nEDM MIEs. Funding for scientific/technical staff is provided to increase levels of effort in selected areas compared to FY 2008 and is directed at the highest priority research, as described below:

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

- ► 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 detector, for R&D efforts in advanced accelerator technologies and techniques, and for neutrino astrophysics and neutrino properties including KamLAND and the neutrino-less DBD experiment CUORE. Reductions to the radioactivity backgrounds of the KamLAND detector allow it to detect lower energy solar neutrinos and to initiate a second generation experiment that will explore the mechanism by which neutrinos oscillate.
- ► The GRETINA MIE, for which fabrication began in FY 2004, is especially important for the study of the nuclear decay and structure of rare isotope nuclei in fast fragmentation beams. The improved position resolution and higher efficiency for high-energy gamma rays compared with presently available gamma-ray detector arrays enable this new detector system to utilize fragmented nuclear beams to open up a new frontier for understanding rare isotope nuclei that may exist in stars and supernovae, but live only fractions of a second. In FY 2009, funding of $2,000,000 is provided to continue fabrication of GRETINA (TEC $17,000,000). The GRETINA project was baselined with CD-2 approval in the fall of 2007. Subsequent reductions in the funding profile in the FY 2008 Appropriation put the TEC at risk and may lead to cost growth, dependent upon fluctuations in foreign exchange rates.
- ► Support is provided for groups at BNL, LANL, and LBNL to conclude the analysis of data and publication of results for the SNO experiment, and conduct R&D and scientific efforts directed at future high priority neutrino experiments.
- ► Support is provided to ORNL to continue to coordinate and play a leadership role in fabrication and development of the scientific program for the FNPB MIE at the SNS. The FNPB project is a beamline at the SNS that will deliver record peak currents of cold and ultra-cold neutrons for studying the fundamental properties of the neutron, leading to a refined characterization of the weak force. Fabrication began in FY 2004 and continues in FY 2009 with funding of $1,500,000 (TEC $9,200,000).
- ► FY 2009 support of $1,100,000 is provided to pursue the measurement of the electric dipole moment of the neutron (nEDM), a high discovery potential experiment at the FNPB (preliminary DOE TPC $17,600,000 - $19,000,000). The nEDM experiment is a joint DOE/NSF experiment. 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. Reductions in the planned funding profile in the FY 2008 Appropriation for the nEDM experiment put the estimated TPC at risk and may lead to cost growth and schedule delays.
- ► Funding is increased within the Low Energy subprogram to support research efforts that are also relevant to the nuclear fuel cycle (+ $4,537,000). Additional funding is provided for this effort in the Nuclear Theory subprogram for Nuclear Data activities. This effort is carried out in collaboration with the Advanced Scientific Computing Research (ASCR) program and other DOE programs. A joint workshop was conducted in FY 2006 with ASCR to identify

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

the leading scientific issues for nuclear cross sections, nuclear data, and related computations.

- ► Funding of $2,000,000 is provided in FY 2009 to continue fabrication of the CUORE experiment (preliminary TPC $8,000,000 - $10,000,000) to search for neutrino-less double beta decay (DBD). This is a joint DOE/NSF project. R&D continues on additional technical approaches to DBD.

	FY 2007	FY 2008	FY 2009
▪ **Other Research**	**4,175**	**5,519**	**8,822**
• **Generic Rare Isotope Beam R&D**	**3,800**	**3,800**	**—**

In FY 2007 and FY 2008, funds were provided for R&D activities aimed at development of generic rare isotope beam capabilities. In FY 2009, these R&D activities become facility-specific and part of the Total Project Cost of the proposed facility for rare isotope beams.

	FY 2007	FY 2008	FY 2009
• **Rare Isotope Beam R&D and Conceptual Design**	—	—	**7,000**

Following a site selection planned in FY 2008, funds are provided in FY 2009 for R&D and to begin conceptual design activities aimed at development of a U.S. facility for rare isotope beams. This facility will enable world-leading research opportunities in nuclear structure, nuclear astrophysics, and fundamental studies, and complement the programs of high capability radioactive ion beam facilities elsewhere in the world.

	FY 2007	FY 2008	FY 2009
• **SBIR and Other**	**375**	**1,719**	**1,822**

In FY 2007, $1,344,000 was transferred to the SBIR program. This activity includes $1,344,000 for SBIR in FY 2008, and $1,426,000 for SBIR in FY 2009. Funding is also provided for other established obligations including the Lawrence and Fermi Awards, which provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

	FY 2007	FY 2008	FY 2009
Operations	**27,888**	**28,253**	**32,163**
▪ **User Facility Operations**	**24,603**	**24,903**	**28,331**

In FY 2009, support is provided to more effectively operate the two National User Facilities, the ATLAS at ANL ($13,740,000) and the HRIBF at ORNL ($14,591,000), for studies of nuclear reactions, structure, and astrophysics, and fundamental interactions at increased levels compared to FY 2008.

In FY 2009, funding supports accelerator operations at ATLAS providing increased beam hours compared to FY 2008 levels, and a full transition from 5 day a week operations to the more cost effective 7 day a week operations mode. AIP funding for upgrading the accelerator with a Californium Rare Ion Breeder Upgrade (CARIBU) project was reduced in the FY 2008 Appropriation and is restored in FY 2009. CARIBU will enhance the radioactive beam capabilities of ATLAS.

In FY 2009, funding supports accelerator operations at HRIBF at increased levels in comparison to the FY 2008 Appropriation. The facility begins to commission a second source and transport beamline (IRIS2) for radioactive ions, which will increase operations efficiency and reliability.

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

In FY 2008, these low energy facilities will carry out about 80 experiments involving over 600 U.S. and foreign researchers. The FY 2008 Appropriation provides support to almost maintain the level of operations achieved in FY 2007. Support in FY 2009 provides increased planned hours of operation with beam to more effectively operate the facilities as indicated below:

	FY 2007	FY 2008	FY 2009
ATLAS Hours of Operation with Beam			
Optimal Hours	7,000	6,600	6,600
Planned Operating Hours	4,736	5,200	5,900
Achieved Operating Hours	4,146	N/A	N/A
Unscheduled Downtime	6.2%	N/A	N/A
Number of Users[a]	200	400	370

	FY 2007	FY 2008	FY 2009
HRIBF Hours of Operation with Beam			
Optimal Hours	5,775	6,100	6,100
Planned Operating Hours	4,350	3,800	4,800
Achieved Operating Hours	4,986	N/A	N/A
Unscheduled Downtime	8.8%	N/A	N/A
Number of Users[b]	90	235	225

- **Other Operations** **3,285** **3,350** **3,832**

  The 88-Inch Cyclotron has been jointly operated by the NP program and NRO and the USAF since FY 2004. The beams of the 88-Inch Cyclotron are used by NP supported researchers for a focused in-house program and for NRO and USAF to simulate cosmic ray damage to electronic components to be used in space. In FY 2009, the NRO and USAF will utilize the 88-Inch Cyclotron for approximately 2,000 hours for their testing program, and NP will utilize it for approximately 3,000 hours for the in-house nuclear physics research program. The NRO and USAF will provide a total of approximately $2,200,000 and NP will provide $3,674,000 for joint operations of the facility in FY 2009.

[a] Counting of users at the NP facilities has been improved to ensure consistent counting methodology from one facility to the next and to remove possible double counting. The more accurate count is reflected for FY 2008 and FY 2009.
[b] Counting of users at the NP facilities has been improved to ensure consistent counting methodology from one facility to the next and to remove possible double counting. The more accurate count is reflected for FY 2008 and FY 2009.

	FY 2007	FY 2008	FY 2009
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	**78,053**	**83,585**	**96,562**

(dollars in thousands)

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Research	
▪ **University Research**	
FY 2009 funding is increased compared to FY 2008, funding personnel at levels needed to support the national Nuclear Physics program. Research concentrates on high priority programs, operations of university accelerators, and non-accelerator initiatives.	+819
▪ **National Laboratory Research**	
• National Laboratory User Facility Research: FY 2009 funding is increased compared to FY 2008, funding personnel at levels needed to support the high priority research efforts and activities at the ATLAS and HRIBF.	+1,024
• Other National Laboratory Research: Funding is reduced for capital equipment (-$1,162,000) mostly as the result of planned funding profiles for ongoing fabrication of the GRETINA, FNPB, CUORE and nEDM MIEs. This decrease is offset by an increase for scientific/technical staff to support high priority research efforts including fundamental research with neutrons (+$5,083,000).	+3,921
Total, National Laboratory Research	**+4,945**
▪ **Other Research**	
The increase reflects the beginning of activities related to the proposed facility for rare isotope beams (+$7,000,000), which is offset by the completion of generic R&D for rare isotope beam capabilities (-$3,800,000). Required SBIR and other obligations increase by $103,000.	+3,303
Total, Research	**+9,067**

	FY 2009 vs. FY 2008 ($000)
Operations	
▪ User Facility Operations: Funding supports HRIBF (+$1,915,000) and ATLAS (+$517,000) at operating levels increased to that of the FY 2008 Appropriation to more effectively operate these two National User Facilities; capital equipment and AIP investments increase (+$996,000) as capital equipment funds that had been redirected to salaries in the FY 2008 Appropriation are restored and AIP projects are supported for the fabrication of a second source and transport beamline for radioactive ions at HRIBF, and to develop an ion source for unique capabilities for radioactive ions at ATLAS.	+3,428
▪ Other Operations: Maintains NP's share of the 88-Inch Cyclotron operations and provides needed funding for maintenance.	+482
Total, Operations	**+3,910**
Total Funding Change, Low Energy Nuclear Physics	**+12,977**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Nuclear Theory			
Theory Research			
University Research	13,524	13,930	15,299
National Laboratory Research	11,640	11,976	13,585
Scientific Discovery through Advanced Computing (SciDAC)	2,200	2,200	2,679
Total, Theory Research	27,364	28,106	31,563
Nuclear Data Activities	5,841	5,924	8,391
Total, Nuclear Theory	33,205	34,030	39,954

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 fundamental research directed at answering the overarching questions that define all three of the frontiers identified by the nuclear science community—quantum chromodynamics, nuclei and nuclear astrophysics, and fundamental symmetries and neutrinos:

What are the phases of strongly interacting matter, and what roles do they play in the cosmos?

What is the internal landscape of the nucleons?

What does QCD predict for the properties of strongly interacting matter?

What governs the transition of quarks and gluons into pions and nucleons?

What is the role of gluons and gluon self-interactions in nucleons and nuclei?

What determines the key features of QCD, and what is their relation to the nature of gravity and spacetime?

and

What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?

What is the origin of simple patterns in complex nuclei?

What is the nature of neutron stars and dense nuclear matter?

What is the origin of the elements in the cosmos?

What are the nuclear reactions that drive stars and stellar explosions?

and

What is the nature of the neutrinos, what are their masses, and how have they shaped the evolution of the universe?

Why is there now more visible matter than antimatter in the universe?

What are the unseen forces that are present at the dawn of the universe, but disappeared from view as it evolved?

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

The subprogram is responding to the need for large dedicated computational resources for Lattice Quantum Chromodynamics (LQCD) calculations that are critical for understanding the experimental results from RHIC and CEBAF. Together with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs, an approximately 5 teraflop prototype computer was developed and implemented in FY 2005 using the custom QCD On-a-Chip (QCDOC) technology. In a joint effort with HEP, development of large-scale facilities began in FY 2006 and will be completed in FY 2009 to provide computing capabilities based on commodity cluster systems. By the end of FY 2008, it is anticipated that the joint HEP/NP Major IT initiative will be operating facilities with an aggregate capacity of 15.6 teraflop/s. The objective for FY 2009 is to acquire an additional 2.4 teraflop/s.

The program is enhanced through interactions with complementary programs overseas, efforts supported by the NSF, programs supported by the DOE HEP program and Japanese supported theoretical efforts related to RHIC at the RIKEN Center at Brookhaven National Laboratory. The Japan U.S. Theory Institute for Physics with Rare Isotope Nuclei (JUSTIPEN) was formed at RIKEN (in Wako, Japan) in FY 2006. JUSTIPEN's purview will be in the area of the physics of (or with) rare isotope nuclei, including nuclear structure and reaction theory, nuclear astrophysics, and tests of the Standard Model using rare isotope nuclei. U.S. participation in JUSTIPEN is in the form of travel grants and subsistence grants to individual theorists interested in collaborating with Japanese scientists.

Nuclear Theory subprogram activities are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

FY 2007 Accomplishments

Significant theoretical advances have been made in all of the three major frontiers of research in nuclear physics today. A few of the most recent accomplishments are:

- The transition from ordinary hadronic matter to the quark-gluon plasma (QGP) as well as properties of the high temperature phase is being studied in lattice QCD calculations. An international collaboration of theorists at Brookhaven National Laboratory, Columbia University, and Bielefeld University, Germany have performed a modern determination (using input quark masses near the physical values) of the transition temperature and find a new value that is about 10% higher than earlier estimates. These new results suggest that an intermediate regime between the QCD transition and freeze-out exists during which the system created in a heavy ion collision persists in a dense hadronic phase. The transition temperature project made intensive use of the two QCDOC computers managed at BNL for the RIKEN-Brookhaven-Research Center and for the Lattice QCD project of the HEP and NP programs.

- It has been speculated, since the 1950's, that the nucleon and its first excited state – Δ(1232) – are both composed of a core of some material that is enclosed in a cloud of mesons. With the advent of Quantum Chromodynamics (QCD), we now know that the core is composed of a complicated mix of quarks and gluons. This mélange can naturally emit and reabsorb mesons, so the old picture of the nucleon and Δ(1232) begins to appear very natural. The testing and verification of this picture is possible using modern electron scattering facilities via pion electroproduction reactions. Over the past ten years, such experiments have been performed at JLab, BNL-LEGS, MIT-Bates and Mainz, and a wealth of data has been accumulated. Working within the context of the recently established Excited Baryon Analysis Center (EBAC) at TJNAF, researchers completed an analysis of the data in 2006, using a dynamical model developed by researchers at Argonne National Laboratory and Osaka University. The results provide the long awaited and conclusive evidence that the early qualitative picture of the nucleon and Δ (1232) is correct; the meson cloud contribution is needed to describe the data at low momentum transfer. Another theoretical model of the quark and gluon core itself, also by TJNAF theorists, verified the need for the meson cloud contribution with similar attributes as that of the dynamical model.

- The auxiliary-field Monte Carlo (AFMC) method, long applied to condensed matter systems, was introduced to nuclear physics about 15 years ago to make predictions of the properties of heavier nuclei where shell model calculations were no longer possible because of the large many-body basis. The AFMC method, however, has been limited by the so-called "sign problem" (path integral of the shell model two-body interactions). Recently researchers at Lawrence Livermore National Laboratory have introduced a prescription to overcome the sign problem and tested it against the exact shell model. The success of these tests (nuclear level densities and ground state properties) indicates the hope of confidently extending AFMC to more massive nuclei (up to $A \approx 120$) and thus bringing the predictive power of the nuclear shell model to challenging problems of nuclear physics not confined to nuclear structure itself. For example, nuclear level densities play an important role in theoretical estimates of nuclear reaction rates needed in various applications including astrophysical nucleosynthesis processes like the *s*-, *r*-, and *rp*-process. In the search for physics beyond the Standard Model, the interpretation of future neutrino-less double beta decay experiments requires the value of the nuclear matrix element of the decay operator; a quantity whose present theoretical estimates differ by about a factor of ten for ^{76}Ge.

- In December 2006, the National Nuclear Data Center at Brookhaven National Laboratory released the next generation evaluated nuclear data library for nuclear science and technology, ENDF/B-VII.0; the major U.S. library dedicated to nuclear reactions. This event coincides with the renewed interest in the nuclear energy option (Advanced Fuel Cycles, Global Nuclear Energy Partnership, and Generation-IV Nuclear Energy Systems). The ENDF/B-VII.0 has been developed by the Cross Section Evaluation Working Group (CSEWG) with a significant contribution from the U.S. Nuclear Data program laboratories (LANL, BNL, NIST, and LLNL). It contains a host of advances over the previous library of computer codes and evaluated data including new methods for including the uncertainties and covariances needed by the physics community, the nuclear energy community and the Nation.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Theory Research	**27,364**	**28,106**	**31,563**
▪ **University Research**	**13,524**	**13,930**	**15,299**

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 2009, funding supports a level of effort for theoretical efforts needed for interpretation of experimental results obtained at the NP facilities. The theoretical efforts are optimized to focus on the high priority activities that are aligned with SC Strategic Plan milestones.

The Institute for Nuclear Theory (INT) at the University of Washington hosts 3 programs per year where researchers from around the world attend to focus on specific topics or questions (annual budget approximately $2,000,000). These programs result in new ideas and approaches, the formation of collaborations to attack specific problems, and the opportunity for interactions of researchers from different fields of study. Often the key papers on the program subjects are either written during the INT programs or based on discussions that took place at the INT. For example, much of the early phenomenology of the Colored Glass Condensate (CGC) for RHIC collisions was developed at the INT. In particular, the prediction of particle suppression at forward rapidity originated at the INT, was subsequently verified experimentally, and remains the strongest evidence for the existence of CGC. The current focus of the nuclear structure community on mean field theory and the energy density functional can be traced back to programs at the INT.

▪ **National Laboratory Research**	**11,640**	**11,976**	**13,585**

Research programs are supported at seven national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL, and TJNAF). In FY 2009, funding provides increased support for scientific staff in order to address theoretical issues important for advancing the national Nuclear Physics program. The nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or programs at that laboratory. The larger size and diversity of the national laboratory groups make them particularly good sites for the training of nuclear theory postdoctoral associates. Funding decisions are influenced by the results of periodic peer reviews of the national laboratory research efforts in the Nuclear Theory sub-program. In FY 2005, the reviewers evaluated each laboratory research group based on the significance of their accomplishments and future program, the scientific leadership, creativity and productivity of the personnel, and the overall cost-effectiveness of the group, which included support by the respective laboratory. The report findings included an adjectival rating along with an indication of the relative ranking of a particular laboratory group compared to the other groups. In response to the review, out-year funding guidance was provided to each group based on performance, issues and availability of funds. In addition, letters of intent were solicited from each laboratory group and subsequently support was provided in FY 2006 for the new Excited Baryon Analysis Center (EBAC) at Jefferson Laboratory. 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.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	**2,200**	**2,200**	**2,679**

Scientific Discovery through Advanced Computing (SciDAC) is an SC program to address major scientific challenges that require advances in scientific computing using terascale resources. Following the re-competition of SciDAC projects in FY 2006, the Nuclear Theory subprogram currently supports efforts in nuclear astrophysics, grid computing, Lattice Gauge QCD theory, and low energy nuclear structure and nuclear reaction theory. An effort on advanced accelerator design was added to the SciDAC portfolio in FY 2007. NP partners in various combinations with HEP, ASCR, NNSA, and NSF on these projects.

Nuclear Data Activities	**5,841**	**5,924**	**8,391**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the physics community and the Nation. The focal point for its national and international activities is the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Funding in FY 2009 provides support for a viable effort in Nuclear Data activities. The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and national laboratories that perform assessment as well as developing modern network dissemination capabilities. The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

Funding is provided to increase research efforts that are relevant to nuclear fuel cycle, including covariant matrix studies, cross section evaluations, relevant computations, and other activities. Funding to support related efforts is provided in the Low Energy subprogram. This effort is carried out in collaboration with the ASCR program. Also a joint workshop was conducted in FY 2006 to identify the leading scientific issues.

Total, Nuclear Theory	**33,205**	**34,030**	**39,954**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Theory Research	
▪ **University Research**	
FY 2009 provides increased support for personnel to focus 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.	+1,369

	FY 2009 vs. FY 2008 ($000)
▪ **National Laboratory Research**	
FY 2009 funding provides increased support for theoretical efforts needed to achieve the scientific goals of the Nuclear Physics program, including the completion of the LQCD initiative with High Energy Physics.	+1,609
▪ **Scientific Discovery through Advanced Computing (SciDAC)**	
FY 2009 funding allows for continued support in the most promising areas for progress in nuclear physics with terascale computing capabilities.	+479
Total, Theory Research	**+3,457**
Nuclear Data Activities	
FY 2009 funding increases to support a viable effort in Nuclear Data related activities (+$401,000). Funding is provided for Nuclear Data activities, which are also related to advanced fuel cycles (+$2,066,000).	+2,467
Total Funding Change, Nuclear Theory	**+5,924**

Isotope Production and Applications

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Isotope Production and Applications[a]			
Isotope Production Infrastructure	—	—	16,720
Research Isotope Development and Production	—	—	3,090
Other Research	—	—	90
Total, Isotope Production and Applications	—[b]	—[b]	19,900

Description

The Isotope Production and Applications subprogram supports the production and processing of isotopes. One-of-a-kind facilities are maintained at the Oak Ridge, Brookhaven, and Los Alamos National Laboratories. These isotopes are used to improve the accuracy and effectiveness of medical diagnoses and therapy, enhance national security, improve the efficiency of industrial processes, and provide precise measurement and investigative tools for materials, biomedical, environmental, archeological, and other research. Actual operations, production, research or other associated isotope activities are funded either by other DOE programs, by the private sector, or by other Federal agency users.

Starting in FY 2009, there is a new subprogram within the Nuclear Physics program entitled Isotope Production and Applications, which consists of the transferred Medical Isotopes Infrastructure program contained in Radiological Facilities program within the Office of Nuclear Energy (NE), as well as support for research isotope development and production. This FY 2009 Budget Request was generated by NE, prior to the transfer to NP. Upon appropriation, the NP Program will work with the community and other relevant federal agencies to define the resources needed to support a viable and robust Isotope Production program, and to identify and resolve issues that impede an adequate supply of stable and radioactive isotopes, with input from scientific advisory committees and the research community. In addition, NP will also consider the conclusions and recommendations from the jointly sponsored National Institute of Health and DOE study by the National Academy of Sciences entitled the *"State of the Science of Nuclear Medicine"* issued in September 2007.

The focus of the Isotope Production and Applications subprogram will be on supporting the research and development, and production of stable and radioactive isotopes, and making them more readily available to respond to the needs of the Nation. Support will be provided for the production of a broad suite of isotopes, important for applications in science, energy, medicine, and industry, and national security. A major objective of this program will be to improve the availability and reliability of research isotopes at

[a] All appropriations for the Isotope Production and Applications subprogram fund a payment into the Isotope Production and Distribution Funds as required by P.L. 101–101 and as modified by P.L. 103–316. Requested funding is required to maintain financial continuity of radioactive and stable isotope research, development, production, processing, distribution, and associated services to commercial and research customers. Funding will also be used to provide radioisotopes and enriched stable isotopes for research and development, medical diagnosis and therapy, isotope applications, and to support nuclear medicine research.
[b] Funding prior to FY 2009 is provided under the Nuclear Energy, Radiological Facilities Management program.

predictable prices needed for medical, national security, and industrial applications. A portfolio of research isotopes will be established with guidance from scientific advisory committees, in consultation with relevant federal agencies and the research community interested in using stable and radioactive isotopes. The NP program has the expertise and experience in operating facilities and developing technologies that are relevant to the production of stable and radioactive isotopes. The transfer of the national isotope production program into the NP program will optimize existing synergies within these two communities, and create new opportunities for collaboration that will benefit both programs and the productivity of the Isotope Production program.

The Isotope Production and Applications subprogram provides radioactive and stable isotope products and associated services to a wide and varied domestic and international market, supporting research by exploring the use of isotopes to advance medical technology. Ultimate applications of isotope products include medical research and health care, industrial research and manufacturing, education, and national defense. The subprogram supports development of new or improved isotope products and services that enable medical diagnoses and therapy and other applications that are in the national interest.

It is important to note that, unlike most Federal programs, the isotope program operates with a revolving fund. The Isotope Production and Applications subprogram fiscal year appropriation is deposited into the Isotope Production and Distribution Program Fund account as established by the 1990 Energy and Water Appropriations Act (Public Law 101-101), as modified by Public Law 103-316. The combination of the annual direct appropriation and revenues from isotope sales maintain financial viability of the Isotope Production and Applications subprogram. The appropriation is used to maintain and upgrade the infrastructure and to develop and produce research isotopes to meet the needs of the U.S. research community.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Isotope Production Infrastructure	—	—	**16,720**
▪ **Oak Ridge National Laboratory (ORNL)**	—	—	**7,860**
• **Buildings 4501 and 7920 Hot Cells**	—	—	**3,800**

All isotope processing activities have been transferred from Building 3047 to Buildings 4501 and 7920. The Department will maintain these facilities in a safe and environmentally compliant condition for processing, packaging, and shipment of radioisotopes and other related services needed in medical diagnostic and therapeutic applications, homeland security applications, and other scientific research used by Federal and non-Federal entities. Activities include facility and shipping container maintenance, radiological monitoring, facility inspections, isotope inventory and shipment scheduling and delivery tracking. Isotope customers pay the cost of isotope processing in these facilities. Funding in FY 2009 is increased by $136,000 over the FY 2008 Appropriation of $3,664,000 within NE.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
• **Buildings 9204-3 and 5500 – Chemical and Materials Laboratories**	**—**	**—**	**3,764**

Maintain the two laboratories in a safe and environmentally compliant condition for the processing, packaging, and shipment of stable isotopes and other services needed in medical diagnostic and therapeutic applications and other scientific research used by Federal and non-Federal entities. Activities include facility maintenance and inspections and customer order and account tracking system maintenance (E-Government). Over the next several years, the Department will continue to phase out the Calutrons in Building 9204-3 at Y-12. Funding in FY 2009 continues at $3,764,000, the same as FY 2008 funding in NE.

• **Infrastructure Upgrades**	**—**	**—**	**296**

Funding will upgrade the alpha-emitting isotope processing capability to include new vacuum chambers and surface barrier detectors, dose calibrator, and installation of liquid nitrogen lines; upgrade the 30-year old control panel and provide for security and quality enhancements to 4501 hot cell to permit the processing of isotopes used in human clinical trials and biological research. This activity was not funded by NE in FY 2008.

▪ **Los Alamos National Laboratory (LANL)**	**—**	**—**	**4,640**
• **Isotope Production Facility/TA-48 Hot Cell, Building RC-1**	**—**	**—**	**3,650**

Maintain facilities in a safe and environmentally compliant condition for the production, processing, packaging, and shipment of radioisotopes and other services needed in medical diagnostic and therapeutic applications, and other scientific research used by Federal and non-Federal entities. Activities include maintenance, radiological monitoring, and facility inspections. Isotope customers will pay the full cost of isotope processing in these facilities. Funding in FY 2009 continues at $3,650,000, the same as FY 2008 funding in NE.

• **Infrastructure Upgrades**	**—**	**—**	**990**

Funding will include extension of the Isotope Production Facility truck bay and rail of the ten ton crane, thus enhancing radiological protection during cask loading; fabrication and installation of shielded detector aperture system on the hot cell; and rapid transfer of targets for efficient production of short lived isotopes. Also a new target station will be installed for target fabrication, target quality control and targetry development. This activity was not funded by NE in FY 2008.

▪ **Brookhaven National Laboratory (BNL)**	**—**	**—**	**3,470**
• **Brookhaven Linear Isotope Producer (BLIP) Building 931 and Hot Cell Building 801**	**—**	**—**	**3,200**

Maintain the BLIP Building 931 and Hot Cell Building 801 facilities in a safe, environmentally compliant condition and state of readiness for the production of radioisotopes and other services needed in medical diagnostic, therapeutic applications, and other scientific research used by Federal and non-Federal entities. Activities include maintenance, radiological monitoring, and

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

facility inspections. Isotope customers will pay the full cost of isotope processing in this facility. Funding in FY 2009 continues at $3,200,000, the same as FY 2008 funding in NE..

• **Infrastructure Upgrades**	—	—	**270**

Funding will provide for replacement of the acid fume scrubber system, installation of a crane/rail system for manipulator repairs in the hot cells, and upgrades to the BLIP beam line. This activity was not funded by NE in FY 2008.

▪ **Other Activities**	—	—	**750**
• **Associated Nuclear Support**	—	—	**750**

This funding provides for requirements applicable to isotope producing sites. Such items include certification of isotope shipping casks, independent financial audits of the revolving fund, and other related expenses. Starting in FY 2009, limited investments will be made in university infrastructure that can achieve production of small quantities of medical research isotopes at lower cost than the national laboratories; this activity was not funded by NE in FY 2008.

Research Isotope Development and Production	—	—	**3,090**

$3,090,000 is provided to support isotope production and research and development activities of commercially-unavailable research isotopes, in response to the needs of the scientific community and based upon peer review. This activity was not funded by NE in FY 2008.

Other Research	—	—	**90**

In FY 2009, this activity includes funding for the Small Business Innovation Research (SBIR) program and the Small Business Technology Transfer (STTR) program. This activity was not funded by NE in FY 2008.

Total, Isotope Production and Applications	—	—	**19,900**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Isotope Production Infrastructure	
▪ **Oak Ridge National Laboratory (ORNL)**	
• **Buildings 4501 and 7920 Hot Cells**	
Funding in FY 2009 is increased by $136,000 over the FY 2008 funding of $3,664,000 in NE.	+3,800
• **Buildings 9204-3 and 5500 – Chemical and Materials Laboratories**	
Funding remains the same as FY 2008 funding in NE.	+3,764

	FY 2009 vs. FY 2008 ($000)
• **Infrastructure Upgrades**	
Funding will allow for infrastructure upgrades at Oak Ridge National Laboratory.	+296
▪ **Total, Oak Ridge National Laboratory**	**+7,860**
▪ **Los Alamos National Laboratory (LANL)**	
• **Isotope Production Facility/TA-48 Hot Cell, Building RC-1**	
Funding remains the same as FY 2008 funding in NE.	+3,650
• **Infrastructure Upgrades**	
Funding will allow for infrastructure upgrades mentioned above.	+990
▪ **Total, Los Alamos National Laboratory**	**+4,640**
▪ **Brookhaven National Laboratory (BNL)**	
• **Brookhaven Linear Isotope Producer (BLIP) Building 931 and Hot Cell Building 801**	
Funding remains the same as FY 2008 funding in NE.	+3,200
• **Infrastructure Upgrades**	
Funding will allow for infrastructure upgrades mentioned above.	+270
▪ **Total, Brookhaven National Laboratory (BNL)**	**+3,470**
▪ **Other Activities**	
• **Associated Nuclear Support**	
Funding in FY 2009 is increased by $200,000 over the FY 2008 funding in NE to allow for university investments such as improvements in target fabrication, modifications in target handling hardware and software, and changes to post-irradiation target processing to improve safety, efficiency and product yield.	+750
Total, Isotope Production Infrastructure	**+16,720**
Research Isotope Development and Production	
New FY 2009 funding reestablishes support for developing and producing medical and scientific research isotopes in short supply, as recommended by the isotope community and the National Academy of Sciences study on the *"State of the Science of Nuclear Medicine"* issued in September 2007.	+3,090

	FY 2009 vs. FY 2008 ($000)
Other Research	
This activity includes funding for SBIR ($80,000) and STTR ($10,000) associated with the increased funding for Research Isotope Development and Production.	+90
Total Funding Change, Isotope Production and Applications	**+19,900**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Construction			
07-SC-02, Electron Beam Ion Source, BNL	5,000	4,162	2,438
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	7,000	13,377	28,623
06-SC-02, Electron Beam Ion Source (PED), BNL	120	—	—
Total, Construction	12,120	17,539	31,061

Description

This subprogram provides for Construction and Project Engineering and Design that is needed to meet overall objectives of the Nuclear Physics program.

In FY 2008, funding for Project Engineering and Design (PED) of the 12 GeV CEBAF Upgrade was reduced as a result of the FY 2008 rescission. This reduction is restored in FY 2009 to maintain the TEC and project scope. Funds are also requested in FY 2009 to begin construction. The Upgrade project will enable scientists to address the mechanism that "confines" quarks together with a scientific portfolio that cannot be addressed at any other machine in the world. Critical Decision-2 (CD-2), Approve Performance Baseline was approved in November 2007.

The Nuclear Physics program provides funding for general plant projects (GPP) at TJNAF and general purpose equipment (GPE) at BNL to address laboratory infrastructure needs. Starting in FY 2009, funds that NP had provided for GPP at BNL are transferred to the Science Laboratories Infrastructure program. Facility capital equipment and accelerator improvement project (AIP) support is provided to the four NP National User Facilities (RHIC, TJNAF, HRIBF, and ATLAS) to develop new capabilities and address facility infrastructure needs. Nuclear Physics will meet the cost and schedule milestones for construction of facilities and fabrication of Major Items of Equipment (MIE) within 10% of baseline estimates.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
07-SC-02, Electron Beam Ion Source, BNL	**5,000**	**4,162**	**2,438**

The Electron Beam Ion Source (EBIS) project, supported jointly by NP and NASA, will replace the high maintenance tandems as the RHIC pre-injector, leading to more cost effective operations and new research capabilities. The TEC is $13,700,000 and the TPC is $14,800,000; and NASA is contributing an additional $4,500,000 above the DOE TPC. EBIS received CD-2 and CD-3 approval in FY 2006. Funding was decreased from planned amounts in the FY 2007 and FY 2008 Appropriations. Restoration of those funds is requested in FY 2009 so that the project can be completed in FY 2010.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	**7,000**	**13,377**	**28,623**

The baseline FY 2008 PED funding was reduced by $123,000 as a result of the FY 2008 rescission. This reduction is restored in FY 2009 to maintain the TEC and project scope. In FY 2009, funding is requested to begin construction of the 12 GeV CEBAF Upgrade (TEC $287,500,000). The upgrade was identified in the 2002 and 2007 NSAC Long-Range Plans as one of the highest priorities for the U.S. Nuclear Physics program and is a near-term priority in the SC 20-Year Facilities Outlook. The upgrade will enable scientists to address one of the mysteries of modern physics—the mechanism of "quark confinement".

Critical Decision-2, Approve Performance Baseline, was approved in November 2007. The proposed cost and schedule profiles reflected in this FY 2009 budget request are consistent with the recommendations made by the DOE Office of Project Assessment Reviews performed in FY 2006 and FY 2007.

	FY 2007	FY 2008	FY 2009
06-SC-02, Electron Beam Ion Source (PED), BNL	**120**	**—**	**—**

PED funding was completed in FY 2007 (see 07-SC-02 above).

	FY 2007	FY 2008	FY 2009
Total, Construction	**12,120**	**17,539**	**31,061**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
07-SC-02, Electron Beam Ion Source, BNL	
Funds provide support in FY 2009 to complete the Electron Beam Ion Source (EBIS) that will replace the aging Tandem Van de Graaff as the heavy ion source for the RHIC complex.	-1,724
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	
Support is provided to begin construction of the 12 GeV CEBAF Upgrade and the reduction in FY 2008 PED funding as a result of the FY 2008 rescission.	+15,246
Total Funding Change, Construction	**+13,522**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
General Plant Projects	7,350	7,350	17,720
Accelerator Improvements Projects	5,196	4,821	6,705
Capital Equipment	26,925	27,593	34,960
Total, Capital Operating Expenses	39,471	39,764	59,385

Construction Projects

(dollars in thousands)

	Other Project Costs	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Unappro-priated Balance
07-SC-02, Electron Beam Ion Source, BNL	1,100	13,700	—	5,000	4,162[a]	2,438	—
06-SC-01, 12 GeV CEBAF Upgrade (PED/Construction), TJNAF	22,500	287,500[b]	500	7,000	13,377	28,623	238,000
06-SC-02, Electron Beam Ion Source (PED), BNL	—	2,100[c]	1,980	120	—	—	—
Total, Construction				12,120	17,539	31,061	

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

(dollars in thousands)

	Total Project Cost (TPC)	Other Project Costs	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Completion Date
STAR Time-of-Flight, BNL[d]	4,800	—	-4,800	2,400	2,400	—	—	FY 2009
GRETINA Gamma-Ray Detector, LBNL	18,800[e]	1,800	17,000[e]	6,500	3,900	3,900	2,000	FY 2011[e]

[a] Funding was decreased from planned amounts in the 2007 and FY 2008 Appropriations. Restoration of those funds are requested in 2009 so that the project can be completed in FY 2010.
[b] Critical Decision-2, Approve Performance Baseline, was approved in November 2007.
[c] The TEC for the EBIS PED (06-SC-02) is included in the total EBIS TEC reflected.
[d] This is a joint U.S./Chinese project and is on track for project completion in FY 2009.
[e] This project has CD-2 approval. Reductions in the planned funding profile as a result of the FY 2008 Appropriation put the established TPC and TEC at risk. The project will have to be re-baselined and the impact on cost and schedule evaluated.

(dollars in thousands)

	Total Project Cost (TPC)	Other Project Costs	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Completion Date
Fundamental Neutron Physics Beamline, ORNL	9,288	88	9,200	4,100	1,500	1,500	1,500	FY 2010
Heavy Ion LHC Experiments, LBNL	13,000-16,000[a]	TBD[a]	TBD[a]	—	1,000	2,000	4,000	FY 2012
PHENIX Silicon Vertex Tracker, BNL)[b]	4,700	—	4,700	—	1,251	2,000	1,200	FY 2010
Neutron Electric Dipole Moment (nEDM), LANL	17,600-19,000[c]	TBD[c]	TBD[c]	—`	770	2,177[c]	1,100	FY 2015
PHENIX Forward Vertex Detector, BNL	4,850[d]	TBD	4,850[d]	—	—	500	2,400	FY 2011[d]
PHENIX Nose Cone Calorimeter, BNL	4,500-4,700[e]	TBD	4,500-4,700[e]	—	—	200	1,200	FY 2012[e]
Cryogenic Underground Observatory for Rare Events (CUORE), LBNL	8,000-10,000[f]	TBD	TBD	—	—	500	2,000	FY 2012
Total, Major Items of Equipment					10,821	12,777	15,400	

[a] CD-1 was approved in December 2006 with a preliminary TPC range of $13,000,000–$16,000,000. The TPC is preliminary and the TPC/TEC/OPC will be baselined at CD-2, planned for 2Q 2008.
[b] This is a joint U.S./Japanese project.
[c] CD-1 was approved in February 2006 with a preliminary TPC range of $17,600,000–$19,000,000. The TPC is preliminary and the TPC/TEC/OPC will be baselined at CD-2 in 2008. Support was reduced from planned funding in the FY 2008 Appropriation, placing cost and schedule estimates for this project at risk.
[d] The TEC and TPC were baselined at a Technical, Cost, Schedule and Management Review. However, funding was reduced relative to the baselined profile with the FY 2008 Appropriation, placing the TPC and TEC at risk. Impacts to cost and schedule are being evaluated.
[e] The TEC and TPC are preliminary and will be baselined at a Technical, Cost, Schedule and Management Review. Funding was reduced in the FY 2008 Appropriation relative to planned amounts, placing cost and schedule estimates at risk for this project.
[f] CD-0 for multiple candidate double beta decay experiments was approved in November 2005 and CUORE represents one of the candidate experiments, with a preliminary TPC range of $8,000,000–$10,000,000. NSF will also make a modest contribution to this Italian/U.S. project. R&D efforts continue on a detector utilizing a different technology.

Fusion Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Fusion Energy Sciences					
Science	144,572	162,910	+994[ab]	163,904	168,435
Facility Operations	146,338[c]	93,504	+7,349[abc]	100,853	301,900
Enabling R&D	20,754[c]	32,766	-10,975[abc]	21,791	22,715
Total, Fusion Energy Sciences	311,664[d]	289,180	-2,632[a]	286,548	493,050

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"

Mission

The mission of the Fusion Energy Sciences (FES) program is to support fundamental research to develop the knowledge base for a new energy source based on the power of the stars, and to expand the underlying scientific foundations of matter at very high temperatures and densities for applications of societal benefit. Research supported by this program concentrates on establishing the knowledge base for future fusion energy sources, plus developing the underlying sciences of plasma physics and high energy density physics. Related work contributes to understanding astrophysics, geosciences, industrial plasma processing, turbulence, and complex self-organizing systems.

Description

Fusion energy systems offer the promise of a fundamentally new and attractive energy source based upon the nuclear fusion process. The Fusion Energy Sciences program is oriented towards developing the scientific underpinnings of potential fusion energy systems. The program also is a steward of the fundamental field of plasma physics, the study of the fourth state of matter, which is a central component of a magnetically confined fusion plasma system. More recently, the program is enhancing its stewardship of the related field of high energy density physics, which underpins inertially confined fusion concepts.

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[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008, as follows: Science ($-1,483,000), Facility Operations ($-851,000), and Enabling R&D ($-298,000).
[b] Reflects a reallocation of funding in accordance with P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008, as follows: Science ($+2,477,000), Facility Operations ($-2,426,000), and Enabling R&D ($-51,000).
[c] For the FY 2009 Request to Congress, ITER funding is consolidated within the Facility Operations subprogram. Previous years' budgets reflected ITER operating expense (Other Project Costs or OPC) funding within the Enabling R&D subprogram; while capital equipment (Total Estimated Cost or TEC) funding was within the Facility Operations subprogram. FY 2007 and FY 2008 amounts in this budget reflect this change ($18,000,000 in FY 2007 and $10,626,000 in FY 2008 is moved from Enabling R&D to Facility Operations).
[d] Total is reduced by $7,286,000: $6,505,000 of which was transferred to the SBIR program and $781,000 of which was transferred to the STTR program.

A defining feature of the FES program is its emphasis on developing the underlying science of potential fusion energy systems. This effort consists of campaigns to develop the requisite understanding of several critical issues, including:

- Integrated Burning Plasma properties;
- Macroscopic equilibrium and stability of plasmas;
- Multi-scale transport of energy and particles;
- Plasma boundary interfaces between a hot plasma and the surrounding material surfaces;
- Interaction of electromagnetic waves and plasma electrons and ions;
- High energy density implosion physics; and
- Fusion engineering science.

These studies have led to a wide range of advances in fusion and plasma related sciences. Some representative advances include:

- Achieved an increase in fusion power output in laboratory experiments by 12 orders of magnitude over the past 3 decades, faster growth than that obtained for computer chip speed.
- Developed the understanding of the tokamak confinement concept needed to support the first demonstration of a burning plasma with significant fusion energy output in the next decade.
- Learned how to control macroscopic plasma equilibrium in magnetic confinement geometries.
- Developed an understanding of nonlinear and resistive macroscopic plasma instabilities, allowing control of high-performance confined plasmas.
- Continued development of a model for plasma turbulence, which will help us to control it as well as energy transport, to improve the prospects for developing a fusion energy system.
- Provided major impetus to establish the scientific field of plasma physics, which underlies a wide range of industrial and scientific applications, including computer chip fabrication, satellite thrusters, materials processing, and clean engines.
- Achieved a deeper understanding of magnetic reconnection and self-organization of magnetized plasmas, with relevance to understanding solar structures to unique confinement configurations for laboratory fusion.
- Discovered complex, three-dimensional magnetic field systems that lead to magnetized plasmas with internal symmetries that may offer attractive energy systems.
- Partnered in developing the emerging new area of physical science of matter at very high energy density, with applications from inertial confinement fusion energy to understanding stellar and astrophysical phenomena.
- Advanced our understanding of the complex interactions of currents and flows that give rise to spontaneous generation of magnetic fields in nature, from the Earth’s magnetic field to astrophysical fields, with applications to simplified plasma confinement systems.

The magnetic fusion energy program is now moving into the burning plasma regime through its participation in the ITER program. The achievement of a burning plasma regime in ITER, wherein much more fusion energy is released than that used to heat the plasma fuel, will provide a fundamental demonstration of the viability of magnetic fusion as a potential new energy source. This will address, for the first time, the strongly nonlinear interactions inherent in the self-heated fusion plasma state. As that regime is approached, the emphasis of the science will necessarily expand from considerations of the hot plasma core regimes to more fully include the multiphase plasma-material phenomena that non-linearly couple to the fusing system.

FES supports research activities in theory, modeling, and experiment across a wide range of scales and capabilities. These range from single-investigator research programs to large-scale national and international collaborative efforts. The FES program funds activities involving over 1,100 researchers and students at approximately 67 universities, 10 industrial firms, 11 national laboratories, and 2 Federal laboratories, all of which are located in 31 states. At the largest scale, the program supports world-class magnetic confinement facilities that are shared by national teams of researchers to advance fusion energy sciences at the frontiers of near-energy producing plasma conditions. Each of the major facilities offers world-leading capabilities for the study of fusion-grade plasmas and their interactions with the surrounding systems. The three major facilities are operated by the hosting institutions but are configured with national research teams made up of local scientists and engineers, researchers from other institutions and universities, and foreign collaborators

While pursuing the long-term development of the required fusion energy knowledge base, this research program also provides tools for understanding fundamental properties of the universe and supports the economic prosperity and national security of the country in the near-term. Research in plasma sciences has improved fabrication techniques for semiconductors and computer chips, material hardening for industrial and biological uses, waste management techniques, and lighting and display techniques. The extreme states of matter studied in high energy density laboratory plasmas that are encountered in inertial confinement fusion studies may offer an alternate path to a fusion energy source. This research is related to the National Nuclear Security Administration (NNSA) stockpile stewardship program and, hence, indirectly supports the national security program of DOE. Related areas of science addressed in these research programs include turbulence and complex systems, multiphase interactions and plasma-material interactions, self-organization of complex systems, astrophysics, geodynamics, and fluids.

Some of the major components of the FES program and their status in the FY 2009 budget year are noted:

- The United States participation in the international ITER project continues in FY 2009, but the U.S. ITER Major Item of Equipment (MIE) project is not fully funded due to FY 2008 Appropriations, which reduced funding from the requested $160,000,000 to $10,626,000. As a result, the United States will be forced to default on most of its 2008 commitments to the ITER Organization. The funding delay will impact the international schedule and will increase U.S. costs; the extent of the cost and schedule impacts is still being assessed.
- The major experimental facilities in the FES program include the DIII-D tokamak at General Atomics (GA) in San Diego, California, the Alcator C-Mod tokamak at the Massachusetts Institute of Technology (MIT) in Cambridge, Massachusetts, and the National Spherical Torus Experiment (NSTX) at Princeton Plasma Physics Laboratory (PPPL) in Princeton, New Jersey. Experiments on major facilities and theory and computer modeling activities, will emphasize developing an understanding of toroidal confinement systems and burning plasma research in support of preparations for the ITER scientific program. In particular, operations and research on existing major tokamak facilities will support final design decisions for ITER and assist in developing operating scenarios for the ITER research program
- The centerpiece of the stellarator program, the National Compact Stellarator Experiment (NCSX) MIE project, is being fabricated at PPPL. The Department of Energy (DOE) and PPPL have recognized that the project cannot be completed within the approved cost. The total project cost for

the NCSX has increased 39 percent over its approved CD-2 baseline, with a greater than 2 year delay in completion. Addressing a charge from the Office of Science, the Fusion Energy Sciences Advisory Committee conducted a scientific and programmatic review of NCSX and the stellarator program and concluded that the NCSX should be completed to maintain U.S. interests in this field. This review plus technical reviews by the Office of Science and Princeton University have provided the necessary input to allow the Department to make the decision to either rebaseline the project or cancel it. Pending this decision in the first half of FY 2008 and a project cost validation, the budget assumes the rebaselining and continued construction of the NCSX project.

- A Fusion Simulation Project (FSP) will be started in FY 2009, taking advantage of the many recent improvements in computational and computing capabilities, as well as a significant amount of preparatory work that has already been done by FES's Scientific Discovery through Advanced Computing (SciDAC) activities. The FSP will be directed at developing a world-leading predictive integrated plasma simulation capability that can be applied to burning plasmas of the type that will be necessary for fusion energy producing power plants. As such, the FSP will represent the embodiment of the goal of developing the knowledge base for a fusion energy system. The FSP will start in FY 2009 and is expected to be completed by FY 2024—with key deliverables targeted at the end of five, ten, and fifteen years
- FES continues to support both the general plasma sciences program that is part of stewarding the field of plasma science and the joint program of research with the NNSA in High Energy Density Laboratory Plasmas (HEDLP) that was started in FY 2008. HEDLP activity within the FES program will be expanded to $24,636,000 in FY 2009.

Finally, it is noted that the research pursued here is one of the nation's main sources of a scientific workforce educated in plasma sciences, and as such provides trained personnel for a wide range of research and development activities in national laboratories, academia, and industry.

Strategic and GPRA Unit Program Goals

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

Strategic Theme 3, Scientific Discovery & Innovation

- Strategic Goal 3.1, Scientific Breakthroughs: Achieve the major scientific discoveries that will drive U.S. competitiveness; inspire America; and revolutionize our approaches to the Nation's energy, national security, and environmental quality challenges.
- Strategic Goal 3.2, Foundations of Science: Deliver the scientific facilities, train the next generation of scientists and engineers, and provide the laboratory capabilities and infrastructure required for U.S. scientific primacy.

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

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

Contribution to GPRA Unit Program Goal 3.1/2.49.00, Bring the Power of the Stars to Earth

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 FES program; (4) exploring innovative confinement options that offer the potential to increase the scientific understanding and to improve the confinement of plasmas in various configurations; (5) investigation of non-neutral plasmas and high energy density physics; and (6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals.

These activities require operation of a set of unique and diversified experimental facilities, including smaller-scale devices at universities involving individual Principal Investigators, larger national facilities that require extensive collaboration among domestic institutions, and an even larger, more costly experiment that requires international collaborative efforts to share the costs and gather the scientific and engineering talents needed to undertake such an experiment. These facilities provide scientists with the means to test and extend theoretical understanding and computer models—leading ultimately to an improved predictive capability for fusion science.

The specific long term (10 year) goals for scientific advancement to which the FES program is committed and against which progress can be measured are:

- **Predictive Capability for Burning Plasmas:** Progress toward developing a predictive capability for key aspects of burning plasmas using advances in theory and simulation benchmarked against a comprehensive experimental database of stability, transport, wave-particle interaction, and edge effects.
- **Configuration Optimization:** Progress toward demonstrating enhanced fundamental understanding of magnetic confinement and improved basis for future burning plasma experiments through research on magnetic confinement configuration optimization.
- **High Energy Density Plasma Physics:** Progress toward developing the fundamental understanding and predictability of high energy density plasma physics.

Funding by Strategic and GPRA Unit Program Goal

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Strategic Goals 3.1, Scientific Breakthroughs and 3.2, Foundations of Science			
GPRA Unit Program Goal 3.1/2.49.00, Bring the Power of the Stars to Earth			
Fusion Energy Sciences	311,664	286,548	493,050

Annual Performance Results and Targets

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
GPRA Unit Program Goal 3.1/2.49.00 (Bring the Power of the Stars to Earth)					
Science					
N/A	Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2005, FES measured plasma behavior in Alcator C-Mod with high-Z antenna guards and input power greater than 3.5 MW. [Met Goal]	Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod, and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2006, FES injected 2 MW of neutral power in the counter direction on DIII-D and began physics experiments. [Met Goal]	Conduct experiments on major fusion facilities leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2007, FES measured and identified magnetic modes on NSTX that were driven by energetic ions traveling faster than the speed of magnetic perturbations (Alfvén speed); such modes are expected in burning plasmas such as ITER. [Met Goal]	Conduct experiments on major fusion facilities leading toward the predictive capability for burning plasmas and configuration optimization. In FY 2008, FES will evaluate the generation of plasma rotation and momentum transport, and assess the impact of plasma rotation on stability and confinement. Alcator C-Mod will investigate rotation without external momentum input, NSTX will examine very high rotation speeds, and DIII-D will vary rotation speeds with neutral beams. The results achieved at the major facilities will provide important new data for estimating the magnitude of and assessing the impact of rotation on ITER plasmas.	Conduct experiments on major fusion facilities to develop understanding of particle control and hydrogenic fuel retention in tokamaks. In FY09, FES will identify the fundamental processes governing particle balance by systematically investigating a combination of divertor geometries, particle exhaust capabilities, and wall materials. Alcator C-mod operates with high-Z metal walls, NSTX is pursuing the use of lithium surfaces in the divertor, and DIII-D continues operating with all graphite walls. Edge diagnostics measuring the heat and particle flux to walls and divertor surfaces, coupled with plasma profile data and material surface analysis, will provide input for validating simulation codes. The results achieved will be used to improve extrapolations to planned ITER operation.

FY 2004 Results	FY 2005 Results	FY 2006 Results	FY 2007 Results	FY 2008 Targets	FY 2009 Targets
N/A	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2005, FES simulated nonlinear plasma edge phenomena using extended MHD codes with a resolution of 20 toroidal modes. [Met Goal]	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2006, FES simulated nonlinear plasma edge phenomena using extended MHD codes with a resolution of 40 toroidal modes. [Met Goal]	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. In FY 2007, FES improved 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. [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 2008, improve the simulation resolution of ITER-relevant modeling of lower hybrid current drive experiments on Alcator C-Mod by increasing the number of poloidal modes used to 2,000 and the number of radial elements used to 1,000 using the leadership class computers at ORNL.	Continue to 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 2009, gyrokinetic edge electrostatic turbulence simulations will be carried out across the divertor separatrix with enhanced resolution down to the ion gyroradius scale.
Facility Operations					
Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.[Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [Met Goal]	Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%. [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%.
Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [Met Goal]	Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. The NCSX team has concluded that the project cannot be completed within the cost and schedule baseline. [Goal Not Met]	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

FES supports a range of small-scale local and mid-scale national facilities to explore both low and high temperature plasmas. The largest of these facilities are three unique mid-sized toroidal confinement experiments, which are operated as collaborative programs for the national fusion research community. Joint experiments among tokamaks around the world are coordinated by the International Tokamak Physics Activity (ITPA).

To develop the knowledge base for a fusion energy system, FES supports a combined experiment, theory and computational modeling research program with two main thrust areas:

- preparation for and execution of studies of burning plasmas in the ITER experiment to develop verified models of this highly nonlinear, self-heated system; and
- resolution of questions that are outside the scope of the ITER program but must be confronted to establish the knowledge base for a first-generation fusion energy power plant on the timescale of the ITER program.

The Fusion Simulation Project (FSP), which will employ world-leading computational capabilities to construct integrated models of the burning plasma state, will codify the understanding developed in the first thrust area. The second thrust area includes studies of plasma confinement concepts for future optimization and studies of the plasma and materials issues encountered in the unique nuclear fusion environment.

Non-fusion general plasma science is studied principally through individual investigator grants that concentrate on theory and/or experimental studies of specific issues of interest. Areas covered include, among others, turbulence, multiphase plasma interactions, generation and destruction of magnetic fields, and waves and instabilities.

The emerging field of high energy density laboratory science is pursued by theory and experiments over a wide range of scales, from individual and small groups to experiments on large national facilities supported by the NNSA. The FES research program will complement the planned high-gain fusion demonstration in NIF by supporting research on energy-related high energy density physics issues that focus on improved efficiency and non-laser approaches.

External factors that affect the level of performance include:

- changing mission needs as described by the DOE and SC mission statements and strategic plans;
- scientific opportunities as determined, in part, by new discoveries, proposal pressure, and scientific workshops;
- 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);
- unanticipated failures in critical components of scientific facilities that cannot be mitigated in a timely manner; and
- strategic and programmatic decisions made by non-SC funded domestic research activities and by major international research centers

Validation and Verification

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

Program Assessment Rating Tool (PART)

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

In the FY 2003 PART review for the FY 2005 Budget, OMB gave the FES program a score of 82% overall which corresponds to a rating of "Moderately Effective." The assessment found that FES has developed a limited number of adequate performance measures which are continued for FY 2009. These measures have been incorporated into this budget request, FES grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of Management and Operating (M&O) contractors. Roadmaps, developed in consultation with the Fusion Energy Sciences Committee (FESAC), will guide triennial FESAC reviews of progress toward achieving the long-term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance and Accountability Report.

OMB has provided FES with three recommendations to further improve performance:

- Develop strategic and implementation plans in response to multiple Congressional requirements.
- Implement the recommendations of expert review panels, especially two major NAS studies, as appropriate.
- Re-engage the advisory committee in a study of how the program could best evolve over the coming decade, including taking into account new and upgraded international facilities.

In response to previous OMB recommendations FES has:

- In accordance with the Energy Policy Act of 2005, prepared several reports which were submitted to Congress in FY 2006.[a]
- Formally charged the FESAC to assess progress toward the long term goals of the FES program.
- Tasked FESAC to prepare a report that identified and prioritized scientific issues and respective campaign strategies. The final report was completed in April 2005, and formed the basis of the September 2005 FES strategic plan.
- Established a Committee of Visitors (COV) process to provide outside expert validation of the program's merit-based review processes for impact on quality, relevance, and performance. The COV reports are available on the web at http://www.science.doe.gov/ofes/fesac.shtml.

During the past three years, COV committees have examined all elements of the FES program in the following order: (1) theory and computation, (2) innovative confinement concepts, high energy density physics, and general plasma science, and (3) tokamak research and enabling R&D. The three COV reports and the FES response to these reports are available at:

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[a] (1) A 'Plan for U.S. Scientific Participation in ITER'; (2) A report describing the management structure of the ITER and estimate of the cost of U.S. participation; and (3) A report describing how U.S. participation in ITER will be funded without a funding reduction in other SC programs.

http://www.ofes.fusion.doe.gov/more_html/fesac/committeeofvisitors.pdf,
http://www.ofes.fusion.doe.gov/more_html/fesac/covlettertohazeltine.pdf,
http://www.ofes.fusion.doe.gov/more_html/fesac/cov_final.pdf, and
http://www.ofes.fusion.doe.gov/more_html/fesac/ofesresponseto2ndcov.pdf.

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

Basic and Applied R&D Coordination

Since 2004, projects sponsored previously by FES in inertial fusion energy (IFE) have been re-directed towards research in high energy density physics (HEDP). Existing, on-going projects in the FES HEDP program include fast ignition, laser-plasma interaction, magnetized high energy density plasmas including plasma jets, and heavy-ion-beam driven warm dense matter. These research areas have been identified by the interagency Task Force on HEDP as belonging to the research category of HEDLP, specifically energy-related research areas of HEDLP. This research overlaps with other areas of HEDLP that have been funded by the NNSA; basic scientific research that is important to nuclear stockpile stewardship including compressible and radiative hydrodynamics, laser-plasma interactions, material properties under extreme conditions, and laboratory astrophysics. NNSA funds these projects under the Stockpile Stewardship Academic Alliance (SSAA) program in the Science Campaign and the National Laser User Facilities program in the Inertial Confinement Fusion program.

The research activities of FES and NNSA in HEDLP will be coordinated under a joint program in HEDLP, with coordinated solicitations, peer reviews, scientific workshops, and Federal advisory functions. The benefits of this coordination is that it will: avoid duplication of effort; include the NNSA funded activities in the SC peer review process; provide better leverage for the FES HEDP projects of the NNSA high energy density (HED) facilities; and stimulate synergies between the two programs. This is in line with the recommendation of the interagency Task Force on HEDP for DOE to provide improved stewardship of the field of HEDLP, while maintaining the interdisciplinary nature of this area of science, by tying the basic scientific research to its roots in application. Thus, the FES funding will be focused mainly on stewarding energy-related areas of basic research in HEDLP, while NNSA's funding will be focused mainly on stewarding the basic research areas of HEDLP that are related to stockpile stewardship.

In May 2007, through the Under Secretary for Science, SC and NNSA jointly sponsored a Workshop in HEDLP held at Argonne National Laboratory to update the scientific research agenda for HEDLP. Three scientific themes emerged from the Workshop: enabling the grand challenge of fusion energy by high energy density laboratory plasmas; creating, probing and controlling new states of high energy densities; and, catching reactions in the act by ultra-fast dynamics. The Workshop participants recommended an expansion of the existing HEDLP research activities which is reflected in the FES request to increase funding in FY 2009 by $8,694,000 over FY 2008 funding.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
High Energy Density Laboratory Plasmas			
Science	15,459	15,942	24,636

Advisory and Consultative Activities

DOE 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 Fusion Energy Sciences Advisory Committee (FESAC) is a standing committee that provides independent advice to the DOE on complex scientific and technological FES program issues.

In FY 2005, FESAC produced a report on "Scientific Challenges, Opportunities, and Priorities for the U.S. Fusion Energy Sciences Program." They identified six themes for scientific campaigns around which the FES program could be organized, which are identified in the Description section. The FES program is being focused on using these campaign topics to define the critical science drivers to motivate program research activities. In addition, the FES program has added the additional campaign topic of burning plasma behavior. A very recent FESAC report (late FY 2007) on research gaps and opportunities arising in the ITER era is being integrated into a long-term strategic planning activity which is being launched in FY 2008.

The National Research Council's Plasma Science Committee, which serves as a continuing connection to the general plasma physics community, recently released a review of plasma science[a]. In 2004 it published an assessment of the DOE Fusion Energy Sciences strategy for addressing the physics of burning plasmas[b]. In addition, the extensive international collaborations carried out by U.S. fusion researchers provide informal feedback regarding the U.S. program and its role in the international fusion effort. These high-level program reviews and peer reviews of research proposals provide a sound basis for developing program plans and priorities and allocating funding.

Program Advisory Committees (PACs) serve an extremely important role in providing guidance to facility directors in the form of program review and advice regarding allocation of facility run-time. Comprised primarily of researchers from outside the host facility, these PACs also include non-U.S. members. They review proposals for research to be carried out on the facility, assess support requirements, and in conjunction with host research committees, provide peer recommendations regarding priority assignments of facility time. Because of the extensive involvement of researchers from outside the host institutions, PACs are also useful in assisting coordination of overall research programs. Interactions among PACs for major facilities assure that complementary experiments are appropriately scheduled and planned, thereby avoiding unnecessary duplication.

Another review mechanism, described previously in the PART Assessment section, involves charging FESAC to establish a COV to review program management practices of selected elements of the FES program each year, such that the entire program is reviewed every three to five years. In general, these COVs have concluded that the FES-supported research programs are of high quality and that the biggest concern has been flat budgets for these programs. Further, the COVs have found that FES program managers are serious, conscientious, and dedicated, and are doing a good job managing their individual program elements.

In May 2006, the third COV completed its review of the research portfolio and peer review process for the FES Tokamak Research and Enabling R&D programs. This committee agreed with the recommendations of earlier COVs, and concluded that there was much evidence that the FES program managers have already implemented many of the recommendations of earlier COVs and were working to make further improvements in programs and processes. However, the committee noted that further

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[a] *Plasma Science – Advancing Knowledge in the National Interest.* Plasma 2010 Committee of the Plasma Science Committee. National Research Council, National Academies Press, 2007, Washington, D.C.

[b] *Burning Plasma – Bringing a Star to Earth.* Burning Plasma Assessment Committee of the Plasma Science Committee. National Research Council, National Academies Press, 2004, Washington, D.C.

work was needed to make the content of the review folders complete and consistent across the programs. The committee also developed the following new recommendations:

- statistics on the award process would be helpful,
- the review sheet used for program renewals should explicitly include a review of progress,
- some form of the proposal score should be communicated to the Principal Investigator (PI) in addition to reviewer comments,
- the reviewer pool size should be increased, and
- the Junior Faculty Award program should be eligible to those outside of basic plasma science.

These recommendations were implemented for proposals requesting funds beginning in FY 2007 and beyond.

Planning and Priority Setting

Planning and setting of priorities is especially relevant since almost all elements of the FES research program will be in flux over the next few years. Research related to magnetic fusion energy will look forward to the ITER burning plasma era, and domestic research activities must evolve to reflect the next step in fusion science. Energy-related HEDP is becoming recognized as a new area of physics in its own right, and growth in activities in this area is expected, especially as NIF comes into operation and moves toward demonstrating significant gain in inertial fusion experiments.

Following the recommendations of the 2004 NAS Burning Plasma Report, participation in ITER is the top priority of the magnetic fusion research program. This includes preparatory research in the domestic program. An initial list of priority issues to be addressed was formed in 2007 in response to the Energy Policy Act of 2005, which required a plan for participation in ITER[a]. More generally, the magnetic fusion science research is organized around six scientific campaigns as defined by the FESAC Priorities study. These are macroscopic stability, multiscale turbulence and transport, plasma-boundary interactions, waves and energetic particles, burning plasma integration, and fusion engineering sciences. The scientific opportunities identified in the 2007 NAS Plasma Science Report and the 2003 Frontiers in High Energy Density Physics studies will be used with peer review to guide funding choices in the general plasma science and HEDP research programs.

Significant Program Shifts

The funding for the Quasi-Poloidal Stellarator development at Oak Ridge National Laboratory (ORNL) is eliminated in FY 2009 to provide funding for higher research and operational priorities.

ITER

Status of ITER Activities

U.S. participation in ITER is a Presidential initiative to internationally 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 for peaceful purposes. The European Union is hosting the site for the international ITER Project at Cadarache, France.

In accordance with Section 972(c)(5)(C) of the Energy Policy Act, the Department has submitted to Congress the following reports: a ‘Plan for U.S. Scientific Participation in ITER’; a report describing the

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[a] Planning for U.S. Fusion Community Participation in the ITER Program. Prepared by the U.S. Burning Plasma Organization, Energy Policy Act Task Group, June, 2007. (Available at: http://www.ofes.fusion.doe.gov/News/EPAct_final_June06.pdf)

management structure of the ITER and estimate of the cost of U.S. participation; and a report describing how U.S. participation in ITER will be funded without a funding reduction in other SC programs. The Department's FY 2009 budget request supports the $214,500,000 for ITER almost entirely from new funds added to the FES budget request.

- **Entry into Force of the ITER Joint Implementing Agreement in 2007:**

  The ITER Joint Implementing Agreement was signed by representatives of the seven ITER Members on November 21, 2006 in Paris, France. The Members also agreed at that time to provisionally apply the Agreement while ratification activities were undertaken. Thus, on December 1, 2006, the international ITER Organization commenced operating on a provisional basis, and since that time the Members have each domestically undertaken the necessary steps for ratification. All seven Members have completed their ratification processes thereby enabling the ITER Joint Implementing Agreement to enter into force on October 24, 2007. For its part, the U.S. deposited its instrument of ratification with the International Atomic Energy Agency (IAEA) on June 8, 2007.

- **Status of the International ITER Organization:**

  Since its inception on December 1, 2006 as a provisional legal entity, significant progress has been made in terms of establishing an operational international ITER Organization. The Director General, the Principal Deputy Director General, and the six Deputy Director Generals (DDGs) are all in place as employees of the international ITER Organization, and staff recruitment is ongoing. The DDGs are responsible for the following areas: Environment, Safety & Health (ES&H) including Quality Assurance and Licensing; Administration; Fusion Science and Technology; Tokamak; Central Engineering and Plan Support; and ITER Control, Data Access and Communications Systems (CODAC), Heating Systems, and Diagnostics. As of November 30, 2007, there were a total of about 200 people working in the international ITER Organization in Cadarache.

  The other key element of the ITER management structure is the ITER Council, which comprises four representatives from each Member. Nominally meeting semi-annually, the Council oversees the Director General and the international ITER Organization. The Council has two subsidiary bodies to provide it with assistance in carrying out its oversight function: the Management Advisory Committee (MAC), and the Scientific and Technology Advisory Committee (STAC). The Council and advisory committees are operational, each having held their first two meetings during the period of provisional application in 2007.

- **Cost Sharing in ITER:**

  For the Construction Phase, the ITER Joint Implementing Agreement stipulates that each of the six non-hosts, including the United States, provide an overall contribution (in-kind and in-cash) equal to a $^{1}/_{11}$ share (about 9.1%) of the total ITER scope of hardware, personnel, and cash (including a central reserve). The corresponding host share for the European Union (EU) is $^{5}/_{11}$ (45.4%). As set forth in the Agreement's Common Understandings on Procurement Allocation, the allocation of in-kind hardware deliverables from each Member has been established based on the same sharing proportions. Should the ITER Council approve new parties to join the current seven ITER Members, the cost sharing arrangements will be adjusted.

- **ITER Design Review:**

  The international ITER Organization concluded a Design Review in November 2007 aimed at updating the 2001 ITER Final Design Report and resolving a number of outstanding design issues in order to establish a new ITER baseline design in 2008. This design will serve as the basis for

Procurement Arrangements being developed between the international ITER Organization and the ITER Members for their "in-kind" hardware contributions. The U.S. was fully engaged in the Design Review process through the participation of scientific and technical experts from throughout the U.S. fusion program in the various Design Review Working Groups. These efforts were funded by the U.S. Contributions to ITER Project.

- **U.S. Contributions to ITER Project:**

The U.S. Contributions to ITER Project is being managed by the U.S. ITER Project Office (USIPO) located at ORNL with partners PPPL, and the Savannah River National Laboratory (SRNL). The USIPO staff includes the Project Manager, Deputy Project Manager, Project Controls Manager, Project Engineering Manager, Procurement Manager, Business Manager, Environmental, Safety and Health (ES&H) and Quality Assurance (QA) Manager, Chief Scientist, Chief Technologist, and managers for the work breakdown structure elements of magnet systems, first wall and shield systems, port limiters, tokamak cooling water system, vacuum pumping and fueling systems, ion cyclotron heating system, electron cyclotron heating system, tokamak plant exhaust processing system, steady-state electric power system, and diagnostics. All U.S. Contributions to ITER Project activities are being overseen by a DOE Federal Project Director at the DOE Oak Ridge Office.

In FY 2006 and FY 2007, and in accordance with DOE Order 413.3A, the FES program and the USIPO have been preparing for Critical Decision 1 (CD-1), Approve Alternative Selection and Cost Range, which was approved in December 2007, and Critical Decision 2 (CD-2), Approve Performance Baseline, in FY 2009–10. It is important that the U.S. schedule for the Critical Decision milestones be consistent with the international ITER Project schedule. The schedule for establishing the performance baseline for the U.S. Contributions to ITER Project at CD-2 is dependent on the ability of the international ITER Organization to finalize the design and schedule for the ITER Project.

The Total Project Cost (TPC) range established at CD-1 for the U.S. Contributions to ITER Project is described in more detail in the Facility Operations subprogram of the FES budget. Funding in FY 2009 provides for $208,500,000 for Total Estimated Cost (TEC) activities and $6,000,000 for Other Project Costs (OPC). The planned FY 2008 funding of $160,000,000 was reduced in December 2007 to $10,626,000 by the FY 2008 Energy and Water Development and Related Agencies Appropriations Act. The resulting curtailment of activities in FY 2008 will impact cost and schedule, the full impact of which is still being assessed. Additional details are provided in the Facility Operations subprogram.

Research activities in the domestic fusion program continue to enhance the physics basis and technology support for ITER. While these activities are of general interest to developing the underlying knowledge base for fusion energy, they synergistically support the move to science research on ITER in the future by:

- Providing research and development (R&D) on ITER physics and technology issues and exploring new modes of operation to extend tokamak and ITER performance;
- Developing safe and environmentally attractive technologies relevant to ITER;
- Advancing fusion simulation as a tool to examine the complex behavior of burning plasmas in tokamaks, which will impact the planning and conduct of experimental operations in ITER;
- Conducting experiments on our national science facilities to develop diagnostics and plasma control techniques that can be extrapolated to ITER; and

- Integrating all that is learned into a forward-looking approach to future fusion applications.

During the negotiations and start-up of the international ITER Organization, the U.S. domestic program has continued to support the domestic technical preparations for the ITER project and has begun to plan for the operation of ITER. These activities are being promoted and coordinated through the U.S. Burning Plasma Organization (USBPO) established in May 2005 for this purpose. The Director of USBPO is also the USIPO Chief Scientist.

The Energy Policy Act of 2005 required development of a plan by DOE for the participation of U.S. scientists in ITER that includes a U.S. research agenda, methods to evaluate whether ITER is promoting progress toward making fusion a reliable and affordable source of power, and a description of how work at ITER will relate to other elements of the U.S. fusion program. The Act requires that this plan be developed in consultation with FESAC, and reviewed by the NAS.

The USBPO produced a 'Plan for U.S. Scientific Participation in ITER' with technical details in May 2006. As called for, the Plan was presented to FESAC for consultation. FESAC reviewed and agreed with the Plan in early June 2006. The Plan was forwarded to Congress on August 11, 2006, for a 60-day review, as required by the Energy Policy Act of 2005 Section 972(c)(4)(A)(i-iii), and it was concurrently submitted to NAS for review. The NAS review started during the summer of 2007. Their final report is expected in late spring, 2008.

- **U.S. ITER Project Accomplishments:**

The USIPO is responsible for the management of the U.S. contributions of hardware, personnel, and cash. Since the establishment of the USIPO in July 2004, the following accomplishments have been made:

- appointments of key management positions within the USIPO were completed;
- preliminary cost and schedule estimates have been prepared, periodically reviewed by SC, and updated to reflect the remaining uncertainties associated with the ITER Project;
- project management documentation required by DOE Order 413.3A has been prepared and approved; and
- the Deputy Secretary of Energy approved CD-0, Approve Mission Need, and CD-1, Approve Alternative Selection and Cost Range as called for in DOE Order 413.3A.

- **Project Management**

FES will continue to apply the Department's project management procedures as required by DOE Order 413.3A and use the oversight functions of the Department to ensure that the U.S. investment in ITER is optimized and protected. This oversight will be accomplished through regular SC Office of Project Assessment "Lehman" Reviews, International ITER Reviews, and the overall coordination and management activities among FES, the USIPO and the international ITER Organization

In preparation for CD-2, the USIPO will develop a performance baseline for the U.S. Contributions to ITER Project that is consistent with the baseline for the international ITER project, which is due to be completed in 2008. After CD-2, FES will track these performance baselines on a regular basis. The target for ITER is the same as for other projects: cost-weighted mean percent variance from established cost and schedule baselines kept to less than 10%.

In addition, now that the ITER Agreement has entered into force and the international ITER Organization is operational, the ITER Council is providing management controls and safeguards.

- **ITER Test Blanket Module Program**

  Since the earlier phases of ITER, a TBM program has been envisioned as a means to demonstrate a key element of fusion technology, namely the breeding of tritium for a closed fuel cycle in a fusion power plant. While not part of the construction scope of ITER as defined in the Joint Implementing Agreement, the seven ITER Members have been engaged in discussions on how to move forward with a TBM program that would be one of several possible upgrades to the ITER facility. A TBM program will have near-term financial implications since certain improvements to the currently designed ITER civil infrastructure must be made to accommodate TBMs. Basic TBM design parameters are already being factored into the ongoing French nuclear regulatory licensing process. The international ITER Organization expects to develop a more definitive TBM plan in 2008. DOE will not enter into any agreements that expand the scope of U.S. financial commitments — contributions to a TBM program would be one example — until the successful construction of the ITER project as originally agreed to in 2003 is assured.

Science

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Science			
Tokamak Experimental Research	45,916	52,870	51,119
Alternative Concept Experimental Research	54,078	57,345	61,694
Theory	23,732	24,486	24,283
SciDAC	6,540	7,138	7,212
Fusion Simulation Project	—	—	1,976
General Plasma Science	14,306	14,648	14,869
SBIR/STTR	—	7,417	7,282
Total, Science	144,572	163,904	168,435

Description

The Science subprogram is developing a predictive understanding of fusion plasmas in a range of plasma confinement configurations. The emphasis is presently weighted towards understanding the plasma state and its properties for stable fusion systems, but increasing emphasis is expected in the areas of multiphase plasma-material states and effects of the nuclear fusion environment as the burning plasma regime is encountered.

A magnetically confined burning plasma will be demonstrated in ITER for the first time. This event would be major steps in establishing the viability of earth-based fusion as a potentially major energy source for the second half of this century.

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 and the fusion environment through an integrated program of experiments, theory, and simulation as outlined in the FESAC report, “Scientific Challenges, Opportunities and Priorities for the Fusion Energy Sciences Program.” This integrated research program focuses on well-defined 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 ITER operation. Research on ITER is expected to provide sufficient information on the complex science of burning plasmas to make a definitive assessment of the scientific feasibility of fusion power. This integrated research program also will benefit from ignition experiments performed at the NNSA-sponsored NIF.

A science-based portfolio approach is the most effective means to ensuring the success of the FES effort to establish the scientific base for practical fusion power. While sufficient understanding is now in hand to build ITER to investigate a burning plasma, significant challenges remain to develop the remaining fusion science and technology knowledge base needed for a potential future demonstration power plant based on what we will learn from ITER. A strong core research program consisting of experiments on domestic and international facilities, comprehensive theory and simulation, and fusion engineering science development is needed to make the exciting discoveries that will identify successful operating regimes and techniques for ITER and beyond, and to develop the skilled workforce needed to carry out this long-term research program.

Plasma science contributes not only to fusion research, but also too many other fields of science and technology, such as industrial processing, national security, space propulsion, and astrophysics. A portfolio approach also advances our knowledge of basic plasma physics and associated technologies, thereby yielding near-term benefits in a broad range of scientific disciplines. An additional objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science and HEDP. Two activities, a NSF/DOE partnership in plasma physics and engineering, and the Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. The ongoing Fusion Science Centers, funded under General Plasma Science, will also foster fundamental understanding and connections to these related sciences.

FY 2007 Science Accomplishments

- ***Basic Plasma Physics Experiment: Implications for Hurricane Modeling:*** Using magnetized electrons as a fluid, the University of Delaware recently observed a classical fluid instability that was first predicted over 100 years ago by A.E.H. Love, but never seen in traditional fluid tank experiments due to the high measurement accuracy required to resolve it in traditional fluid experiments. The Delaware studies suggest that Love's predicted instability may be common in fluid flows. One example of a physical system where the instability may occur is in incipient hurricanes. The Delaware results could lead to improved modeling of how incipient hurricanes either break up or become organized as they cross the ocean.
- ***Localized Magnetic Chaos Controls Dangerous Edge Instability:*** The edge plasma in high performance tokamak plasmas is a remarkable thermal insulator (temperatures drop millions of degrees in only a few centimeters), but is subject to impulsive instabilities that produce periodic bursts of heat and particles that can damage the walls of the tokamak. Scientists at DIII-D have succeeded in eliminating these bursts (called Edge Localized Modes [ELMs]) by applying small 3-D magnetic perturbations to the normal 2-D magnetic field of the tokamak. This technique has been applied successfully on the Joint European Torus (JET) facility, and variations of the underlying theory are being tested on DIII-D to contribute to optimizing the design requirements of control coils for ITER.
- ***Understanding how Microwaves Can Sustain a Tokamak Plasma:*** In order to operate in steady state, a tokamak-based power plant would require that a toroidal plasma current be sustained through a combination of pressure-driven currents and externally applied non-inductive techniques. One of the most efficient external techniques utilizes microwaves which can penetrate into the plasma, and deliver toroidal momentum to a localized population of high energy electrons. Recently such a toroidal plasma current was sustained in Alcator C-Mod using phased microwaves at or near world-record efficiencies. Detailed measurements of the location of the driven current and distributions of the current-carrying electrons have been used to validate state-of-the-art computational models (used in SciDAC projects), providing increased confidence in the predictive capability of these models for fusion applications.
- ***China-U.S. Partnership Enables Control of the Experimental Advanced Superconducting Tokamak (EAST):*** Because all major coil systems on ITER will be superconducting, it will be important to gain operational experience on controlling plasmas in superconducting advanced

tokamaks prior to ITER operation. Using the EAST/DIII-D Plasma Control System (PCS), developed at GA and based on the multi-cpu DIII-D PCS, the newly completed EAST facility at the Academy of Sciences Institute of Plasma Physics (ASIPP) in Hefei, China achieved first plasma within three days of beginning startup operations in September 2006. The extraordinary rapidity of this startup process of a completely new type of tokamak is due to the partnership between the ASIPP team and a team of experienced U.S. physicists and control experts from GA and PPPL who supported EAST startup, both onsite and remotely.

- ***First High-Fidelity Simulations of Sawtooth Oscillations in Tokamaks:*** Sawtooth oscillations are periodic events occurring near the center of tokamak plasmas which can have a significant impact upon the performance of burning plasmas. Understanding and controlling sawteeth is therefore important for the operation of ITER. Researchers at the SciDAC Center for Extended Magnetohydrodynamic Modeling (CEMM) have performed self-consistent simulations of repetitive sawtooth cycles for a small tokamak, the Current Drive Experiment, using the two extended nonlinear MHD codes of the Center, and obtained excellent agreement between the two codes and good agreement with the experiment. These CEMM simulations represent a significant first step toward a first-principles predictive understanding of this important phenomenon.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Tokamak Experimental Research	**45,916**	**52,870**	**51,119**

The tokamak magnetic confinement concept has 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 GA and Alcator C-Mod at MIT. Both DIII-D and Alcator C-Mod are operated as national collaborative science facilities with research programs established through public research forums, program advisory committee recommendations, and peer review. There is also a very active program of collaboration with comparable facilities abroad aimed at establishing an international database of tokamak experimental results. In association with the International Tokamak Physics Activity (ITPA), both DIII-D and Alcator C-Mod continue to give high priority to their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

In FY 2009, U.S. tokamak research will continue to focus on supporting the ITER project. DIII-D will utilize its upgraded microwave heating system to further explore active plasma control and optimization techniques needed for ITER using electron cyclotron current drive. C-Mod will pursue a program with high magnetic field and high power densities incident on ITER-candidate materials for plasma facing components, while utilizing recent hardware upgrades to improve control of various plasma parameters and pursue “hybrid” advanced operating scenarios for ITER. In international collaborations, the scope of joint ITPA experiments will be enhanced to accommodate new experiments in support of ITER. These activities will improve the understanding of key ITER physics issues, including plasma stability control, disruption mitigation, wave-particle interaction, energy and particle transport, and development of improved plasma discharges for burning plasma studies on ITER.

As the new superconducting tokamaks in China (EAST) and Korea (Korean Superconducting Tokamak Advanced Research (KSTAR) project) begin research operations, collaborations with those programs will be expanded to investigate steady state physics and technology issues.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

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 heating and 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**	**24,531**	**27,060**	**26,249**

The DIII-D tokamak is the largest magnetic fusion facility in the United States. DIII-D provides for considerable experimental flexibility and has extensive diagnostic instrumentation to measure the properties of high temperature plasma. It also has unique capabilities to shape the plasma and provide feedback control of error fields that, in turn, affect particle transport in the plasma and the stability of the plasma. DIII-D has been a major contributor to the world fusion program over the past decade in the areas of plasma turbulence, energy and particle transport, electron-cyclotron plasma heating and current drive, plasma stability, and boundary layer physics using a “magnetic divertor” to control the magnetic field configuration at the edge of the plasma. The divertor is produced by magnet coils that bend the magnetic field at the edge of the tokamak out into a region where plasma particles following the field are neutralized and pumped away.

The primary goal of the DIII-D program is to establish the scientific basis for the optimization of the tokamak approach to fusion energy. This will be accomplished by advancing basic scientific understanding across a broad front of fusion plasma topical areas including transport, stability, plasma-wave physics, and interactions with physical boundaries. Integrating this knowledge in cross cutting research campaigns will help enable the success of ITER and enhance burning plasma research. Over the past few years, the investigation of ITER-relevant discharge scenarios, including the development of advanced enhanced performance scenarios, has gained emphasis in the DIII-D experimental program.

In FY 2009, the DIII-D program will continue to focus on experiments to provide solutions to key ITER issues and build a firm physics basis for ITER program planning. With the completion of an upgrade to the infrastructure power system and the ability to use all auxiliary heating systems at full power (including all eight neutral beam sources), the DIII-D program will have a very significant set of control tools to demonstrate integrated performance of advanced tokamak operating modes. Priority experiments will be conducted to assess the optimum plasma configuration through the active control of internal plasma parameters and the mitigation of instabilities. This will include the continued examination of techniques to detect, lessen, and avoid the effects of plasma disruptions. The DIII-D program will also be able to accommodate a number of ITPA joint experiments with the international community.

▪ **Alcator C-Mod Research**	**8,267**	**9,600**	**9,030**

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 all-metal walls to accommodate high power densities. By virtue of these characteristics, Alcator C-Mod is particularly well suited to operate in plasma regimes that are

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

relevant to ITER. The facility has made significant contributions to the world's fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks, all of which are important integrating issues for burning plasmas.

In FY 2009, C-Mod will conduct a strong research program primarily in support of ITER. Experiments will focus on elucidating the physics of self-generated plasma rotation and on advanced operating "hybrid" scenarios for ITER involving shallow reversal of the shear in the confining magnetic fields. These scenarios are known to have special stability and good confinement properties and are capable of enabling longer discharge duration. High power lower hybrid microwave and ion cyclotron radio frequency wave heating and current drive capabilities of the facility will be employed to this goal.

Other ITER-relevant topics that the C-Mod team will continue to focus on in FY 2009 include plasma surface interaction with all-metal walls (especially in the divertor area), measuring the effects of and mitigating disruptions in the plasma, understanding the physics of the plasma edge in the presence of large heat flows, controlling the current density profile for better stability, and helping to build international cross-machine databases using dimensionless parameter techniques. C-Mod will continue participation in many joint experiments organized by the ITPA involving all seven ITER members.

	FY 2007	FY 2008	FY 2009
▪ **International**	**4,710**	**4,982**	**4,900**

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad in Europe, Japan, China, South Korea, the Russian Federation, and India—the ITER members, and conduct comparative studies to enhance the understanding of underlying physics. The U.S. programs in return host visiting scientists from the international community for participation in U.S. experiments. The FES program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. This allows U.S. scientists to have access to the unique capabilities of fusion facilities that exist abroad. These include the world's highest performance tokamaks JET in England and Japan Torus 60 Upgrade [JT-60U] in Japan), a stellarator (the Large Helical Device in Japan), a superconducting tokamak (Tore Supra in France), AxiSymmetric Divertor Experiment Upgrade (ASDEX-UG) and Tokamak Experiment for Technology Oriented Research (TEXTOR) in Germany, and several smaller devices. In addition, the United States is collaborating with South Korea on KSTAR, as that device begins operation, and with China on research using EAST. The U.S. collaboration on EAST was instrumental in that device achieving its first plasma on September 26, 2006 and its first elongated, diverted plasmas in early 2007. These collaborations provide a valuable link with the 80% of the world's fusion research that is conducted outside the United States and provide a firm foundation to support ITER activities.

The United States is a major participant in the ITPA, which identifies high-priority physics needs for ITER and assists in their implementation through collaborative experiments among the major international tokamaks, and analysis and interpretation of experiments for extrapolation to ITER.

In FY 2009 the United States will participate in high priority research activities in support of ITER. These include joint ITPA experiments with teams from the large tokamak programs JET and JT-60U, some joint experiments on medium sized tokamaks such as Tore Supra in France and TEXTOR and ASDEX-UG in Germany, and other joint ITER-relevant experiments in the areas of plasma wall

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

interactions, plasma instabilities, and first wall design considerations for ITER. Some of the above activities will be impacted as the level of U.S. participation in steady-state physics and technology issues on KSTAR and EAST is expanded and total funding for International activities decreases slightly in FY 2009. These activities will prepare U.S. scientists for participation in burning plasma experiments on ITER. In addition to these tokamak collaborations there are also some collaborations, in the stellarator area with Japan and the European Union.

▪ **Diagnostics**	**3,768**	**4,141**	**3,912**

Support for the development of unique measurement capabilities (diagnostic instruments) will continue. Diagnostic instruments serve two important functions: to provide a link between theory/computation and experiments for an understanding of the complex behavior of the plasma in fusion research devices; and to provide sensory tools for feedback control of plasma properties in order to enhance device operation. In FY 2009, research will include the development of diagnostics for fundamental plasma parameter measurements, state-of-the-art measurement techniques, and R&D for ITER-relevant diagnostic systems. Diagnostic systems will be installed and operated on current experiments in the United States and on non-U.S. fusion devices through collaborative programs.

The key areas of diagnostic development research are those identified in the FESAC report "Scientific Challenges, Opportunities and Priorities for the U.S. Fusion Energy Sciences Program," April 2005.

A competitive peer review of the diagnostics development program was conducted in FY 2007 for funding that began in FY 2008.

▪ **Other**	**4,640**	**7,087**	**7,028**

Funding in this category supports educational activities such as research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, and summer internships for undergraduates. In addition, there is funding for outreach efforts related to fusion science and enabling R&D and operational costs for the U.S. Burning Plasma Organization and FESAC.

Alternative Concept Experimental Research	**54,078**	**57,345**	**61,694**

This program element broadens the fusion program by exploring the science of confinement optimization in the extended fusion parameter space, with plasma densities spanning twelve orders of magnitude, by seeking physics pathways to improve confinement, stability, and reactor configurations. Through this scientific diversity, the program element adds strength and robustness to the overall fusion program by lowering overall programmatic risks in the quest for practical fusion power in the long term, for which economic and environmental factors are important. At present, three alternate concepts are being pursued at the larger-scale, proof-of-principle level. A number of concepts are also being pursued at a concept-exploration level with smaller-scale experiments, as well as research in establishing a knowledge base for high energy density plasmas. The smaller scale experiments and the cutting-edge research have proven to be effective in attracting students, and strongly contribute to fusion workforce development and the intellectual base of the fusion program. The research has also resulted in new ideas for the larger toroidal devices, including ITER.

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
▪ **NSTX Research**	**14,608**	**16,730**	**16,163**

NSTX is one of two large spherical torus confinement experiments in the world; the other is the MegaAmp Spherical Tokamak (MAST) in the United Kingdom. The spherical torus is an innovative confinement device that produces a plasma that is shaped like a sphere with a hole through its center. The properties of a spherical torus plasma are predicted to be different from a conventional tokamak plasma, which is "donut" shaped. For example, theory predicts that a spherical torus plasma will be stable even when very high ratios of plasma-to-magnetic field 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 cost-effective facility for carrying out the nuclear engineering science research needed to provide the integrated knowledge base for a fusion energy system.

In FY 2009, the NSTX team will continue to carry out research on topics that are important to ITER, as well as on the development of the spherical torus concept, such as confinement and stability of highly elongated, low-aspect ratio plasmas at high temperatures and densities. Research on macroscopic stability will focus on understanding the physics of resistive wall mode stabilization and control as a function of rotation. Research on energetic particle modes will investigate how the plasma current density is modified by super-Alfvénic ion driven modes. In the area of integrated, high performance plasma operation, the NSTX team will study conditions in which the toroidal plasma current is maintained for durations longer than the plasma current redistribution time using various current drive methods. To achieve high performance, the NSTX team will use increased plasma elongation to maximize the contribution of the self-driven "bootstrap" current and active stabilization to control pressure-driven instabilities.

▪ **Experimental Plasma Research**	**16,476**	**17,050**	**13,288**

Experimental Plasma Research was started to explore Innovative Confinement Concepts (ICC). In the ICC program, a number of small concept-exploration level facilities have been constructed, an ICC-centric theory center has been formed, and several small topic-specific investigations have been supported. The facilities built include spheromaks, field-reversed configurations, a levitated dipole, a flow-stabilized z-pinch, centrifugally confined magnetic mirrors, and electrostatic confinement. In general, these cover emerging concepts for plasma confinement and stability. These studies have intrinsic value to the plasma science and fusion energy missions of the FES program since they provide unique tests and extensions of our understanding of confined plasmas. In that sense, these programs complement the larger tokamak programs to help establish the predictive understanding of fusion plasma behavior. The program will undergo a peer review in FY 2009, the goal of which is to select a portfolio of concepts to generate sufficient experimental data to elucidate the underlying physics principles upon which these concepts are based and, as needed, to develop computational models of promising concepts to a sufficient degree of scientific fidelity to allow an assessment of the relevance of those concepts to future fusion energy systems. The funding reduction in FY 2009 is largely the result of two changes: the Sustained Spheromak Physics Experiment (SSPX) project at LLNL will be completed in FY 2008; and the Quasi-Poloidal Stellarator is not supported in FY 2009 to provide funding for higher research and operational priorities.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
▪ **HEDLP**	**15,459**	**15,942**	**24,636**

High energy density laboratory plasma physics is the study of ionized matter at extremely high density and temperature. According to the recent National Academy of Sciences report on plasma science[a], high energy density (HED) physics begins when matter is heated or compressed (or both) to a point that the stored energy in the matter exceeds about 10^{10} Joule per cubic meter. This is approximately the energy density of solid material at about 10,000 Kelvins, and corresponds to a pressure of about 100,000 atmospheres. HED conditions exist in the interior of the Sun where hydrogen has been fused to produce energy for billions of years. Supernovae, gamma ray bursts, accretion disks around black holes, pulsars, and astrophysical jets are examples of HED astrophysical phenomena. On Earth, HED conditions can only be created transiently in the laboratory by using intense pulses of lasers, particle beams (electrons or ions), plasma jets, magnetic pinches, or their combinations. Because of its potentially immense impact on energy security, the NAS report recommended that SC provide stewardship of HED plasma science related to inertial fusion including the use of magnetized targets.

In response to a number of recent NRC and other federally sponsored studies, the interagency Task Force on HEDP recommended that the stewardship for HEDLP be improved. However, the Task Force also recommended that the Federal stewardship be organized in such a way as to maintain the multi-disciplinary nature of the field. Thus the HED science related to stockpile stewardship should remain under the purview of NNSA while the HED science related to energy applications should be the focus for the FES stewardship for the field. The FES program in HEDLP follows closely the recommendations of the interagency Task Force as well as the NAS, within the limits of available budgets.

In FY 2009, the proposed budget will fund research in on-going areas and increased funding is requested for new initiatives as the HEDLP Joint Program evolves. The on-going areas include studies of warm dense matter driven by heavy ion beams, fast ignition, and magnetized high energy density plasmas including plasma jets. A rolling series of competitive solicitations will be started to identify initiatives to be supported under the Joint Program in HEDLP. These solicitations will cover the above three areas and other relevant HEDLP areas, such as laser-plasma interactions, compressible hydrodynamics, and laboratory astrophysics. The merit of these areas for funding as well as the amount of funding available as part of the solicitation will be determined by competitive peer-review and recommendations of pending workshops and conferences. In addition, a program in HEDLP will be initiated in FY 2009 at LLNL.

▪ **Madison Symmetrical Torus**	**6,760**	**6,910**	**6,915**

The goal of the Madison Symmetrical Torus (MST), at the University of Wisconsin-Madison, is to obtain a fundamental understanding of the physics of reversed field pinches (RFPs), particularly magnetic fluctuations and their macroscopic consequences, and to use this understanding to develop the RFP fusion configuration. The RFP is geometrically similar to a tokamak, but with a much weaker magnetic field that reverses direction near the edge of the plasma. Research in the RFP's self-organization properties has astrophysical applications and may lead to a more cost-effective

[a] *Plasma Science – Advancing Knowledge in the National Interest.* Plasma 2010 Committee of the Plasma Science Committee. National Research Council, National Academies Press, 2007, Washington, D.C.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

fusion system. The plasma dynamics that limit the energy confinement, the ratio of plasma pressure to magnetic field pressure, and the sustainment of the plasma current in a RFP are being investigated in this experiment. MST is one of the four leading RFP experiments in the world, and is unique in that it pioneered the reduction of magnetic fluctuations by current density profile control. In recent years, this approach has led to a ten-fold increase in energy confinement time.

In FY 2009, the major plans of the MST program are to complete the construction of a multi-point charge exchange recombination spectroscopic system and measure a range of ion temperatures, and to begin measurement of electron temperature fluctuations using a fast Thomson scattering system. The plan also includes improving experimental facilities such as incorporation of a long pulse, high power neutral beam, a diagnostic neutral beam for motional stark effect diagnostics, and a programmable power supply for controlling the toroidal loop voltage.

	FY 2007	FY 2008	FY 2009
▪ **NCSX**	**775**	**713**	**692**

This funding supports the research portion of the program to be executed with the NCSX at PPPL, which involves participation and a leadership role within the National Compact Stellarator Program (NCSP). PPPL, ORNL, and LLNL are the participants in NCSX research that keep abreast of physics developments in domestic and international stellarator research, factoring those developments into planning of the NCSX experimental program, as well as preparation of long-lead-time physics analysis tools for NCSX application. These tools have a dual use: setting physics requirements for hardware upgrades and interpreting data from future NCSX operation. The NCSX team will analyze plasma equilibria to establish requirements and physics designs for in-vessel magnetic diagnostic upgrades and trim coils; develop design requirements for the initial plasma-facing components and edge diagnostics; and conduct a research forum to continue the community-wide planning of NCSX research campaigns, obtain feedback on NCSX plans and priorities, and identify collaborator interests and opportunities.

	FY 2007	FY 2008	FY 2009
Theory	**23,732**	**24,486**	**24,283**

The Theory program provides the conceptual scientific underpinning for FES by supporting three of its thrust areas: burning plasmas, fundamental understanding, and configuration optimization. Theory efforts meet the challenge of describing the complex multiphysics, multiscale, non-linear plasma systems at the most fundamental level and, in doing so, generate world-class science. These descriptions—ranging from analytic theory to highly sophisticated computer simulation codes—are used to interpret results from current experiments, plan new experiments on existing facilities, design future experimental facilities, and assess projections of their performance. The program focuses on both tokamaks and alternate concepts. Work on tokamaks is aimed at developing a predictive understanding of advanced tokamak operating modes and burning plasmas—both of which are important to ITER—while the emphasis on alternate concepts is on understanding the fundamental processes determining equilibrium, stability, and confinement for each concept. The theory program also provides the input needed in the FES large-scale simulation efforts that are part of the SciDAC portfolio and, together with SciDAC, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and controlled.

The Theory program is a broad-based program with researchers located at six national and federal laboratories, over thirty universities, and several private companies. Theorists in larger groups, located mainly at national laboratories and private industry, generally support major experiments, work on large

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

problems requiring a team effort, or tackle complex issues requiring multidisciplinary teams. Those at universities tend to support smaller, innovative experiments or work on more fundamental problems in plasma physics while training the next generation of fusion plasma scientists.

Some of the issues to be addressed by theory researchers in FY 2009 include the turbulent transport of toroidal and poloidal momentum in tokamak plasmas and the understanding of spontaneous toroidal rotation, progress toward a predictive understanding of particle and electron transport, the physics of the edge pedestal and the transition from the Low to the High (L-to-H) confinement modes in tokamaks, the formation of edge and internal transport barriers, the first-principles formulation of moment closures in extended magnetohydrodynamics (MHD) models, the calculation of atomic and molecular collision processes of importance in fusion reactors, the study of the effect of magnetic islands on the stability properties of 3-D equilibria in stellarators and other innovative confinement concepts, the understanding of fast magnetic reconnection in high temperature fusion plasmas, and the development of predictive integrated computational models for tokamak plasmas.

	FY 2007	FY 2008	FY 2009
SciDAC	**6,540**	**7,138**	**7,212**

The SciDAC program is a set of coordinated research efforts across all SC programs with the goal of achieving breakthrough scientific advances through computer simulation that are otherwise impossible using theoretical or laboratory studies alone. By taking advantage of the exponential advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-disciplinary collaboration among physical scientists, mathematicians, computer scientists, and computational scientists. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit the emerging capabilities of terascale and petascale computing.

The current FES SciDAC portfolio includes eight projects, which are set up as strong collaborations among 29 institutions with 44% of the funding going to national laboratories, 38% going to universities, and 18% going to private industry. Of these, five are focused on topical science areas, such as macroscopic stability, the simulation of electromagnetic wave-plasma interaction, the study of turbulent transport in burning plasmas, and the physics of energetic particles. During the last funding period (FY 2005–FY 2007), these projects developed high-performance computational tools which have provided us with new and significant insights into questions of fundamental importance in fusion plasma science. These included the simulation of mode conversion of radio frequency (RF) waves in tokamak plasmas, the modeling of the sawtooth instability and Edge Localized Modes (ELMs) in tokamaks, and the understanding of the inward spreading of ion temperature gradient driven turbulence from the edge to the core of tokamak plasmas. These projects were competitively reviewed in 2007. The new and renewed projects resulting from this competition will be focusing their efforts in FY 2008–FY 2010 on the needs of burning plasmas and ITER and will address issues such as the interaction of RF waves with the edge plasma, the development of a predictive understanding of turbulent transport with emphasis on the electron, particle, and momentum transport channels using computational models with increased physics fidelity, and the macroscopic stability of fusion plasmas using extended nonlinear MHD codes with more complete physics models and realistic parameters including validation with experiments. In addition, a new project focused on the physics of energetic particles has been added to our SciDAC portfolio, recognizing the critical importance of this area for ITER and burning plasmas.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

The remaining three projects, which were jointly funded by the FES and ASCR programs in FY 2006 and FY 2007 for a five-year period, are known as Fusion Simulation Prototype Centers or proto-FSPs and focus on code integration and computational framework development in the areas of edge plasma transport, interaction of RF waves with MHD, and the coupling of the edge and core regions of tokamak plasmas. In FY 2009, these centers will continue to focus their efforts on issues important to burning plasmas and ITER, such as the development of physics-based models of RF control of sawtooth oscillations and neoclassical tearing modes, the development of a first-principles edge pedestal model for ITER, and the development of advanced computational frameworks for integrated simulations.

Fusion Simulation Project	**—**	**—**	**1,976**

The Fusion Simulation Project (FSP) is a computational initiative led by FES with collaborative support from ASCR. The FSP is aimed at the development of a predictive simulation capability relevant to ITER and other toroidal fusion devices, taking advantage of the high performance computing resources at our leadership class facilities. In May 2007, a national workshop was held to refine the long-term vision for the FSP and develop a detailed description of what must be accomplished during the next five years to make progress toward an integrated simulation capability. The workshop report was recently evaluated by FESAC, which recommended that the project move forward to a Project Definition phase, and is now in the process of being evaluated by the ASCR Advisory Committee.

General Plasma Science	**14,306**	**14,648**	**14,869**

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 makes contributions in many basic and applied physics areas. Principal investigators at universities, laboratories, and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Fusion Science Centers, the Plasma Physics Junior Faculty Award Program, the General Plasma Science program carried out at the DOE laboratories, and basic plasma physics user facilities at laboratories and universities (sharing costs with NSF where appropriate). The Fusion Science Centers perform 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 strengthen the connection between the fusion research community and the broader scientific community. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. FES will continue to share the cost with NSF of the multi-institutional plasma physics frontier science center started in FY 2003.

SBIR/STTR	**—**	**7,417**	**7,282**

In FY 2007, $6,505,000 and $781,000 were transferred to the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, respectively. The FY 2008 and FY 2009 amounts are the estimated requirements for the continuation of these programs.

Total, Science	**144,572**	**163,904**	**168,435**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Tokamak Experimental Research	
▪ **DIII-D Research**	
Redirecting resources to higher priorities will require some staff reductions but will support the DIII-D national research team at the level necessary to conduct experiments and analysis relevant to burning plasma physics and ITER at the planned 10 weeks of operation.	-811
▪ **Alcator C-Mod Research**	
Redirecting resources to higher priorities will result in a reduced level of effort in analyzing experimental results.	-570
▪ **International**	
Funding for the Tore Supra exchange with the European Union is reduced slightly to provide funding to support other higher priority program needs.	-82
▪ **Diagnostics**	
Redirecting resources to higher priorities will result in a reduction in the level of effort for developing new base-program and ITER-relevant diagnostics.	-229
▪ **Other**	
The decrease will slightly reduce education outreach activities.	-59
Total, Tokamak Experimental Research	**-1,751**
Alternative Concept Experimental Research	
▪ **NSTX** Redirecting resources to higher priorities will require some reduction in scientific staff and a reduced level of effort on experiments and data analysis.	-567
▪ **Experimental Plasma Research**	
The decrease reflects completion of SSPX at LLNL ($2,282,000), and elimination of funding for the Quasi-Poloidal Stellarator ($-1,111,000) to provide support for higher research and operational priorities in FY 2009 and in the future, as well as an overall reduction of effort in this area of $369,000.	-3,762
▪ **HEDLP**	
The increase is for the expansion of DOE's efforts in on-going and new projects in fast ignition and dense plasmas in ultrahigh magnetic fields including plasma jets, and for initiation of a program in HEDLP at LLNL. The technical scope of the program will expand according to the recommendations of the recent Workshop in HEDLP held at Argonne National Laboratory (May 2007). Funding will be awarded through competitive peer-reviewed solicitations that will be launched in FY 2008.	+8,694

	FY 2009 vs. FY 2008 ($000)
▪ **Madison Symmetrical Torus**	
Funding is increased slightly from FY 2008 resulting in continued full operation of the device.	+5
▪ **NCSX**	
With the delay in the project schedule, the experimental research program for NCSX is reduced slightly.	-21
Total, Alternative Concept Experimental Research	**+4,349**
Theory	
Redirecting resources to higher priorities will result in a slight reduction in the overall theory efforts in both tokamaks and alternates.	-203
SciDAC	
The increase will strengthen efforts in targeted areas critical to burning plasmas and ITER, in particular energetic particle effects and turbulent transport.	+74
Fusion Simulation Project	
The funding in FY 2009 will support the planning and design of this new project.	+1,976
General Plasma Science	
The increase will support additional high-quality grants funded under the NSF/DOE Partnership in Basic Plasma Science and Engineering.	+221
SBIR/STTR	
Support for SBIR/STTR is funded at the mandated level.	-135
Total Funding Change, Science	**+4,531**

Facility Operations

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Facility Operations			
DIII-D	32,138	34,600	31,811
Alcator C-Mod	13,993	15,510	14,177
NSTX	18,917	22,100	19,274
NCSX (MIE)	15,822	15,900	19,560
GPP/GPE/Other	5,468	2,117	2,578
U.S. Contributions to ITER (MIE TPC)	60,000[a]	10,626[a]	214,500
Total, Facility Operations	146,338	100,853	301,900

Description

The mission of the Facility Operations subprogram is to manage the major fusion research facilities to the highest standards of overall performance, using merit evaluation and independent peer review. The facilities are 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, including installation of diagnostics, required to optimize plasma performance for the experimental programs, will be accomplished in accordance with the highest standards and with minimum deviation from approved cost and schedule baselines.

Our 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.

As a result of the FY 2008 Appropriations, DIII-D, Alcator C-Mod, and NSTX have been provided additional funding to increase operating weeks during FY 2008. The funding requested in FY 2009 will provide research time for about 500 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. national science investment.

The NCSX project at PPPL was expected to be completed in FY 2009. As described previously, the project cost and schedule baseline must be changed for the project to continue. This budget assumes that

[a] Starting in FY 2009, the U.S. Contributions to ITER project TEC and OPC funds are consolidated and requested in this subprogram. FY 2007 and FY 2008 funding displayed here reflects this change. Previous budgets reflected the OPC costs under the Enabling R&D subprogram ($18,000,000 in FY 2007 and $10,626,000 in FY 2008).

the project will be rebaselined. The Department will formally make the decision on whether to proceed with this rebaselining in the first half of FY 2008.

The FY 2009 Request provides for the fourth year of funding for the U.S. Contributions to ITER project. The FY 2009 funding of $214,500,000 in the Facilities Operations subprogram provides for: operation of the USIPO; U.S. design, R&D, and hardware contributions; U.S. personnel seconded to the international ITER Organization; cash for common needs such as infrastructure, hardware assembly, and installation of ITER components; and cash for the international ITER Organization central reserve.

The schedule of the work to be completed in FY 2009 will be re-planned based on the impact to the project of the funding reduction contained in the FY 2008 Energy and Water Development and Related Agencies Appropriations Act.

Funding is also included in this subprogram for general plant projects (GPP) and general purpose equipment (GPE) at PPPL. GPP and GPE supports essential facility renovations, and other necessary capital alterations and additions to buildings and utility systems.

FY 2007 Facility Operations Accomplishments

- **DIII-D at GA, San Diego**

  DIII-D completed the additions and modifications to the microwave system infrastructure to support three additional long-pulse microwave tubes (gyrotrons), supported experiments with two of the new tubes, and began operational testing of the third gyrotron. Two of the ion cyclotron frequency (ICRF) systems were also refurbished and resumed operation, providing up to 3 megawatts (MW) of auxiliary power for experiments. Spare neutral beam ion sources were successfully manufactured in order to support operation of an eighth neutral beam in FY 2009.

- **Alcator C-Mod at MIT**

  Alcator C-Mod was outfitted with a divertor cryopump which has allowed much better density control of the discharge which enables operation in high confinement regimes not possible before. Many other minor upgrades to diagnostic systems were also performed.

- **NSTX at PPPL**

  The NSTX operations group has nearly completed the design of a system to provide electron cyclotron heating and electron Bernstein wave heating (ECH/EBW system) based on a source generating either 200 kilowatts (kW) power at 28 gigahertz (GHz) or 100 kW at 15.3 GHz. When completed, this system will enable an initial experimental test of the EBW heating in NSTX.

- **NCSX at PPPL**

  PPPL completed winding 15 of the 18 NCSX modular coil winding forms (MCWFs) and initiated fabrication of the toroidal field coils. The MCWFs are steel structures that support the modular coil windings and position them with high accuracy. Installation of heating/cooling risers and diagnostics continued on the vacuum vessel sector. The vacuum vessel is a highly shaped structure with stringent requirements on vacuum quality and magnetic permeability.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
DIII-D	**32,138**	**34,600**	**31,811**

Support is provided for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. A facility power infrastructure upgrade will be completed in FY 2008 to support maximum utilization of the existing auxiliary heating systems, and modifications to the coil connections to allow long pulse operations will be finished. Along with the recently regained capability to operate all eight neutral beam heating sources, this gives the DIII-D tokamak exceptional tools to explore integrated advanced tokamak operating modes. In FY 2009, 10 weeks of single shift plasma operation will be conducted, during which time essential scientific research will be performed as described in the Science subprogram. Funding will be provided for improvements to the microwave heating system to upgrade its capability to actively track and suppress plasma instabilities.

DIII-D	FY 2007	FY 2008	FY 2009
Optimal hours (estimated)	1,000	1,000	1,000
Achieved Operating Hours	512	720	400
Total Number of Users	220	240	240

	FY 2007	FY 2008	FY 2009
Alcator C-Mod	**13,993**	**15,510**	**14,177**

Support is provided for operation, maintenance, minor upgrades, and improvement of the Alcator C-Mod facility and its auxiliary systems, including initiation of the tokamak outer divertor redesign and improvements of the Charge Exchange Recombination and soft X-ray diagnostics to allow better measurements in plasma rotation studies. In FY 2009, C-Mod will be operated for 13 weeks, focusing on ITER-relevant experiments.

Alcator C-Mod	FY 2007	FY 2008	FY 2009
Optimal hours (estimated)	800	800	800
Achieved Operating Hours	480	480	416
Total Number of Users	105	105	105

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
NSTX	**18,917**	**22,100**	**19,274**

Support is provided for operation, maintenance, and a few diagnostics upgrades, including the full poloidal charge exchange recombination spectroscopy system, a fast-ion D-alpha camera, divertor diagnostics, and installation of next-step fluctuation diagnostics. In FY 2009, there is funding for 11 weeks of operation mostly to explore long pulse, high beta experiments.

NSTX	FY 2007	FY 2008	FY 2009
Optimal hours (estimated)	1,000	1,000	1,000
Achieved Operating Hours	508	720	440
Total Number of Users	140	150	150

NCSX	**15,822**	**15,900**	**19,560**

Funding is requested in FY 2009 for the continuation of the NCSX MIE. This project was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. PPPL will continue the fabrication of the major components and assembly of the entire device. This fusion confinement concept has the potential to be operated without plasma disruptions, leading to power plant designs that are simpler and more reliable than those based on the current lead concept, the tokamak. The NCSX design will allow experiments that compare confinement and stability in tokamak and stellarator configurations.

The NCSX MIE project has experienced higher than expected costs to date with fabrication activities and with the complicated assembly process still ahead, it is now evident that this MIE project cannot be completed within the approved cost and schedule baseline. PPPL performed a bottoms-up cost and schedule estimate to complete the project, and is preparing a revised baseline. The total project cost has increased at least 39 percent over its second cost baseline (now 69 percent over the original baseline). SC charged FESAC to conduct a scientific and programmatic review of NCSX and the stellarator program to determine the value to both the national and international stellarator communities. FESAC reported its findings in October 2007 and concluded that the NCSX should be completed to maintain U.S. interests in this field. Princeton University then performed an external independent technical review in October/November 2007 to determine whether PPPL could build and maintain NCSX successfully. The Review Team concluded that PPPL can succeed in building and maintaining this stellarator. These reviews have provided the necessary input to allow DOE to make the decision to either rebaseline the project or cancel it. That decision will be made in the first half of FY 2008. If the decision is to proceed with the fabrication of NCSX, DOE’s Office of Construction and Engineering Management will conduct an External Independent Review to assess the proposed cost and schedule baseline. The FY 2009 request for the NCSX MIE assumes validation and approval of the proposed rebaseline.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

Milestones for NCSX are shown in the following table:

FY 2007	FY 2008	FY 2009
Complete winding of one half of the modular coils.	Complete winding of all of the modular coils.	This budget assumes a re-baseline of the NCSX MIE Project which is estimated to be ~$50 million over budget and 34 months behind schedule. For additional discussion of this situation, see the Facility Operations subprogram section.

GPP/GPE/Other	**5,468**	**2,117**	**2,578**

These funds are provided primarily for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability, and research needs. This category also funded the ORNL move of all fusion personnel and equipment from the Y-12 to the X-10 site. This move will be completed early in FY 2008.

U.S. Contributions to ITER TPC	**60,000**[a]	**10,626**[a]	**214,500**
U.S. Contributions to ITER OPC (R&D)	**18,000**	**10,626**	**6,000**
U.S. Contributions to ITER TEC	**42,000**	**—**	**208,500**

The U.S. Contributions to ITER project provides hardware (including the supporting design and R&D), personnel, cash for common expenses, and cash to the international ITER Organization's central reserve.

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. Because of the intense plasma heating by fusion products, it will also access previously unexplored areas of energetic particle physics. Because of the very strong heat and particle fluxes emerging from ITER plasmas, it will extend our knowledge base of plasma-boundary interaction well beyond previous experience. The new regime of plasma physics that can be explored for long duration, and the interactions among the anticipated phenomena, are characterized together as "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 three decades and on the technical know-how flowing from fusion technology research and development programs around the world. The ITER design has been internationally validated by wide-ranging physics and engineering work, including detailed physics and computational analyses, specific experiments in existing fusion research facilities and dedicated technology developments and tests performed from 1992 to the present.

[a] Starting in FY 2009, the U.S. Contribution to ITER project TEC and OPC funds are consolidated and requested in this subprogram. FY 2007 and FY 2008 funding displayed here reflects this change. Previous budgets reflected the OPC costs under the Enabling R&D Subprogram ($18,000,000 in FY 2007 and $10,626,000 in FY 2008).

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

The ITER device is a long-pulse tokamak with elongated plasma shape and a single-null poloidal divertor. In nominal inductive operation, the goal is to produce 500 MW of deuterium-tritium fusion power for a burn duration of at least 400 seconds, with a power gain factor of at least 10, which is close to what should be required in a power plant.

Safety and environmental characteristics of ITER reflect a consensus among the Members on safety principles and design criteria for minimizing any possible adverse consequences of ITER operation on the public, the operators, and the environment. This consensus is supported by results of analysis of all postulated events and their consequences.

DOE will comply with all U.S. environmental and safety requirements such as the National Environmental Policy Act applicable to the ITER work that will be conducted in the U.S.

DOE's commitment to the international ITER Organization is a $^{1}/_{11}$th share (~9.1%) of the international ITER construction project costs per the value estimate in the ITER Joint Implementing Agreement, which is identical to the other non-host participants. In addition to scientists and engineers assigned to the international ITER Organization, the U.S. has provided one senior management staff member to the international ITER Organization: the Deputy Director General for Tokamak Systems. All U.S. personnel assigned to the international ITER Organization will comply with the environmental and safety requirements of the host country and with the applicable U.S. legal requirements.

The requested FY 2008 funding of $160,000,000 was reduced in December 2007 to $10,626,000 by the FY 2008 Energy and Water Development and Related Agencies Appropriations Act. While the conference report accompanying the Act eliminated funding for the ITER project TEC, it did not direct termination of the project. Therefore, DOE plans to use the funds provided for the ITER project OPC ($10,626,000) plus previous year carryover funds to preserve the core U.S. ITER Project Team and, to the extent possible, meet minimum U.S. commitments to the ITER Organization in France until FY 2009 funds become available. Further design work, long-lead hardware procurements, and additional cash contributions to the ITER Organization will be delayed until that time.

In FY 2009, the $214,500,000 requested will be used to resume the full range of U.S. participation in ITER. These activities will focus on material bonding R&D for first wall components; design and analysis of the central solenoid magnet structure, first wall and shield, port limiters, tokamak cooling water system, fueling pellet injector, tokamak exhaust processing system, ion and electron cyclotron heating transmission lines, and diagnostics; and initiating long-lead procurements of toroidal field magnet conductor materials, tokamak cooling water system components, and first articles of the first wall and shield modules. In addition, the funds will be used to support the USIPO, provide U.S. secondees to the international ITER Organization, and provide cash contributions to the international ITER Organization per the terms of the ITER Joint Implementing Agreement. Some work originally planned for FY 2009 will be delayed into FY 2010 and beyond.

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		

The schedule and funding projections for the U.S. Contributions to ITER project are reflected in the tables at the end of the Facility Operations subprogram budget. The FY 2008 funding reduction will cause U.S. hardware fabrication and delivery to be delayed, which will lead to cost growth. The schedule and cost estimate for the U.S. Contributions to ITER project remains preliminary until the baseline scope, cost, and schedule are established at CD-2, planned for FY 2009-2010.

Total, Facility Operations	**146,338**	**100,853**	**301,900**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
DIII-D	
The decrease in funding for FY 2009 will reduce the weeks of operation from 18 in FY 2008 to 10 in FY 2009. Minor upgrades to the microwave steering systems (launchers) will be completed to improve the capability to actively track and suppress instabilities.	-2,789
Alcator C-Mod	
The decrease in funding for FY 2009 will reduce the weeks of operation from 15 in FY 2008 to 13 in FY 2009.	-1,333
NSTX	
The decrease in funding for FY 2009 will reduce the weeks of operation from 18 in FY 2008 to 11 in FY 2009.	-2,826
NCSX	
This increase supports the estimated rebaseline for the NCSX project.	+3,660
GPP/GPE/Other	
This reflects a modest increase in general infrastructure repairs and upgrades at the PPPL site.	+461
U.S. Contributions to ITER project	
This increase provides for the fourth year of funding for the MIE project. Activities in FY 2009 will focus on resuming the full range of U.S. participation in ITER to include advancement and/or completion of various design, analysis, and R&D activities and long-lead procurements for major U.S. components.	+203,874
Total Funding Change, Facility Operations	**+201,047**

U.S. Contributions to ITER project

	Fiscal Quarter				Total Estimated Cost ($000)	Total Project Cost ($000)
	Procurements Initiated	Procurements Complete	Personnel Assignments to Foreign Site Start	Personnel Assignments to Foreign Site Complete		
FY 2006 Budget Request	3Q FY 2006	4Q FY 2012	2Q FY 2006	4Q FY 2013	1,038,000	1,122,000[a]
FY 2007 Budget Request	4Q FY 2006	4Q FY 2012	2Q FY 2006	FY 2014	1,077,051	1,122,000[a]
FY 2008 Budget Request	1Q FY 2008	4Q FY 2014	2Q FY 2006	FY 2014	1,078,230	1,122,000[a]
FY 2009 Budget Request	2Q FY 2009	4Q FY 2014– 4Q FY 2017[b]	2Q FY 2006	FY 2014– FY 2017	TBD	1,450,000– 2,200,000[b]

ITER Financial Schedule
Total Project Costs (TPC)[c]

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Costs	Total Project Costs
2006	15,866	3,449	19,315
2007	42,000	18,000	60,000
2008	—	10,626	10,626
2009	208,500	6,000	214,500
Outyears	TBD	TBD	TBD

Estimated ITER TPC Range

Although the ITER Joint Implementing Agreement has entered into force, there is still much to be done in preparation for construction. As the project enters 2008, a number of significant cost risks remain that could affect the U.S. ITER TPC. The sources of potential cost growth can be categorized as follows: The FY 2008 Energy and Water Development and Related Agencies Appropriations Act signed on December 26, 2007 that reduced the U.S. ITER project funding from $160,000,000 to $10,626,000; actions taken by the ITER Council and the international ITER Organization; external factors outside of DOE's control; and design maturity.

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[a] Mission Need (CD-0) was approved in July 2005 with a preliminary TPC of $1,122,000,000 (the U.S. cap). The funding profile was also preliminary.

[b] Alternative Selection and Cost Range (CD-1) was approved in December 2007 with a TPC range of $1.45 to $2.20 billion and a completion schedule range of FY 2014 to FY 2017. During FY 2008 and FY 2009, U.S. reviews will be conducted to validate the cost and schedule estimates for the U.S. Contributions to ITER project. These reviews will reflect the impact of the FY 2008 Energy and Water Development and Related Agencies Appropriation Act. In addition, international ITER Project activities in FY 2008 will establish the international cost and schedule baselines which can have an effect on the U.S. Contributions to ITER project. The baseline TPC, including the funding profile, will be established at CD-2 planned for FY 2009-2010. The FY 2009 Budget Request is for continued engineering design and long-lead procurements only. Engineering design may include limited fabrication and testing of design concepts.

[c] A complete baseline funding profile, including the outyears, will be established at CD-2, which is anticipated to be in FY 2009–2010.

Among the aspects under the international ITER Organization's purview, the principal cost drivers are the overall project schedule, design changes and other actions impacting hardware scope and manufacturing costs, and licensing/regulatory requirements. The international ITER Organization is developing a schedule for the construction phase that includes detailed inputs from the seven Domestic Agencies, which is to be made available by mid-2008. Likewise, there are several technical issues in the reference design to be resolved in 2008 that may require design changes, some of which may increase the U.S. ITER TPC. There may also be cost impacts from French and European regulatory requirements imposed on the ITER design.

External factors include changes in currency exchanges rates, escalation rates, commodity prices, and market conditions for hardware procurement. The ITER Joint Implementing Agreement requires cash contributions from the Members to be made in Euros, which has already cost the U.S. ITER Project considerably more than was previously foreseen due to the exchange rate. Prices for raw materials used in manufacturing U.S. supplied hardware have also been steadily increasing. The responses to date from industry in response to USIPO requests for price quotes have indicated that the future bidding climate will be unfavorable for many types of hardware.

Finally, the reference design for ITER is not mature in certain areas such as the Central Solenoid Magnet System, for which the U.S. has manufacturing responsibility. This means that there could be adverse cost impacts as the design is finalized prior to fabrication.

Prior to the FY 2008 funding reduction, all of these risks were evaluated to develop a TPC range for CD-1. It was determined that the bottom of the range should be set at $1.45 billion. The increase from the previous $1.122 billion preliminary TPC to this level accounts for those risks that were deemed to be highly likely to occur. The $1.45 billion estimate still includes a reasonable contingency amount (equal to 27 percent of the hardware cost). The other contributors to the increase from $1.122 billion were overall project schedule slippage, deterioration of the dollar versus the Euro, and commodity price growth. The difference between $1.45 billion and the top end of the TPC range, $2.2 billion, essentially represents additional contingency for known risks in the above categories as well as an amount for unidentified risks. Most of the TPC cost increase is related to potential actions of the international ITER Organization and external factors that could impact U.S. hardware costs. The impact of the funding reduction in the FY 2008 Energy and Water Development and Related Agencies Appropriations Act will be evaluated as part of developing the schedule and cost baselines for CD-2.

ITER Related Annual Funding Requirements

The current estimate in the table below incorporates the terms of the ITER Joint Implementing Agreement on cost sharing during operations, deactivation and decommissioning. Specifically, it considers the procedure for converting currencies into Euros and the 20-year period of annual contributions to the decommissioning fund in conjunction with ITER operations.

	(dollars in thousands)	
	Current Estimate	Previous Estimate
FY 2015–FY 2034[a]		
U.S. share of annual facility operating costs including commissioning, maintenance, repair, utilities, power, fuel, improvements, and annual contribution to decommissioning fund for the period 2015 to 2034. Estimate is in year 2015 dollars.	80,000	56,900
FY 2035–FY 2039		
U.S. share of the annual cost of deactivation of ITER facility for the period 2035–2039. Estimate is in year 2037 dollars.	25,000	18,200

[a] FY 2016 is the estimated date for start of operations based on the current international ITER schedule.

Enabling R&D

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Enabling R&D			
Engineering Research	16,075	15,991	17,924
Materials Research	4,679	5,800	4,791
Total, Enabling R&D	20,754[a]	21,791[a]	22,715

Description

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 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.

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, including ITER. Enabling R&D efforts provide both evolutionary development advances in present day capabilities that will make it possible to enter new plasma experimental regimes, such as burning plasmas, and nearer-term technology advancements enabling international technology collaborations that allow the U.S. to access plasma experimental conditions not available domestically. A part of this element is oriented toward investigation of scientific issues for innovative technology concepts that could make revolutionary changes in the way that plasma experiments are conducted, such as microwave generators with tunable frequencies and steerable launchers for fine control over plasma heating and current drive. This element includes research on blanket technologies that will be needed to produce and process tritium for self-sufficiency in the fuel supply. This element also supports research on safety-related issues; enabling both current and future experiments to be conducted in an environmentally sound and safe manner. Another activity is system studies of the most scientifically challenging concepts for fusion research facilities that may be needed in the future as well as identifying critical scientific issues and missions for the next stage in the FES program. Finally, analysis and studies of critical scientific and technological issues are supported, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on applications of fusion.

[a] Starting in FY 2009, ITER OPC is consolidated and requested in Facility Operations. Funding of $18,000,000 in FY 2007 and $10,626,000 in FY 2008 previously reflected in this subprogram is now reflected in the Facility Operations subprogram.

The Materials Research element focuses on the key science issues of materials for practical and environmentally attractive uses in fusion research and future facilities. This element uses both experimental and modeling activities, which makes it more effective at using and leveraging the substantial work on nanosystems and computational materials science being funded by the Basic Energy Sciences program and other government-sponsored programs, as well as making it more capable of contributing to broader 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 is accomplished through a Virtual Laboratory for Technology (VLT), with community-based coordination and communication of plans, progress, and results.

In FY 2009, research efforts will continue supporting the development of enabling technologies that enhance plasma performance on both our current and planned domestic machines as well as for our international collaborations with existing facilities such as JET and possibly with new facilities such as Korea's KSTAR and China's EAST. In addition, resources will be used to continue to develop a database for materials that can be used in future facilities, to address potential issues that may occur during ITER operation, and to develop the next generation of technology that could be tested in current facilities or in ITER.

FY 2007 Enabling R&D Accomplishments

- ***Modeling improves understanding of experimental data:*** Development of science-based fracture toughness assessment methods is vital to determining how materials will react given certain conditions and ensuring safe and reliable operation of structures in the harsh fusion environment. As part of the U.S.-Japan (DOE-Japan Atomic Energy Agency [JAEA]) fusion materials collaboration, multiscale modeling was performed to elucidate the micromechanical mechanisms underpinning the shape of the fracture toughness master curve, the relationships among yield stress increase, ductile to brittle transition temperature (DBTT) shift, and specimen size effects in fracture toughness assessments. For a large number of steels, test temperatures, and strain rates, the results show that yield dynamics and fracture dynamics are the same. Analysis of the different relationships between DBTT shift and yield stress increase for conventional reactor pressure vessel steels and reduced activation ferritic/martensitic steels for fusion illustrates the important role of irradiation on strain hardening.

- ***Complex Fluid Dynamics modeled:*** Simulation capabilities are critical to elucidate the complex, coupled, nuclear science phenomena expected in liquid metal systems and in experiments in the magneto-nuclear environment of fusion facilities. The first three dimensional, fully viscous and inertial, magnetohydrodynamic (MHD) simulations of liquid metal flows through a complex geometry flow distribution manifold have been performed this year at the University of California at Los Angeles. These simulations show the strong impact of MHD interactions between highly conductive liquid metal and plasma magnetic confinement. These first-of-a-kind simulations may lead to effective flow control and help ensure uniform flow distribution (and thus heat removal) in liquid metal cooled structures. They are being used to develop an understanding of the impact of the magnetic field strength, orientation, and spatial distribution with various geometric configurations and electrical coupling techniques.

- ***Improvements in Edge Localized Mode (ELM) Mitigation:*** ELM mitigation is essential to reduce large transient heat loads, which can damage the plasma facing surface of the containment vessel. If left unmitigated, plasma ELMs in ITER and follow-on devices could potentially deliver large transient heat loads to the material surfaces that contain the burning plasma. ELM mitigation techniques, for both current and future experiments, were investigated using high frequency small pellets to generate small, benign ELMs. An experiment to test this scheme was installed on the DIII-D tokamak and is being used to extrapolate the necessary pellet sizes and speeds required to mitigate potential ELMs. Modeling shows that the same technology developed for fueling can be employed to produce steady state ELM mitigation. The frequent injection of cold fuel pellets is a promising technique for reducing the severity of these transient heat loads and mitigating their effects.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Engineering Research	**16,075**	**15,991**	**17,924**
▪ **Plasma Technology**	**13,531**	**13,391**	**13,351**

Plasma Technology efforts will focus resources on developing enabling technologies for current and future machines, both domestically and internationally, and on addressing potential ITER operational issues in the area of safety and plasma materials interactions. In addition, a new U.S.-Japan Collaborative Program (Tritium Irradiation Thermofluid American-Japanese Network [TITAN]) will be initiated on plasma facing and blanket materials for use in future experiments. During FY 2009, the following specific activities will be supported:

- Continue studies of tungsten-carbon-beryllium mixed materials layer formation and redeposition with attached hydrogen isotopes in the Plasma Interaction with Surface and Components Experimental Simulator facility at the University of California at San Diego, and the Tritium Plasma Experiment at the Idaho National Laboratory (INL). Results will be applied to evaluate tritium accumulation in plasma facing components that will occur during ITER operation.
- Initiate a new series of material science experiments under the TITAN cost-sharing collaboration with Japan in the Safety and Tritium Applied Research Facility at INL to resolve key issues of tritium behavior in materials proposed for use in fusion systems.

Besides the above activities, research will be conducted on plasma facing components, heating technologies, and blanket concepts that could be tested in ITER. In addition, this category funds research in safety and plasma-surface interaction and modeling that support addressing potential issues that could be encountered during operation of ITER or future devices.

▪ **Advanced Design**	**2,544**	**2,600**	**4,573**

This effort will continue to focus on system studies of devices that could lead the program toward a demonstration power plant. The studies will be done using a team of individuals drawn from all over the research community to assure highly innovative solutions to the many issues facing the program.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

In FY 2009, the Pathways study initiated in FY 2007 will be completed. The final effort of the project will be to gain a consensus on what the remaining major R&D areas are, which must be addressed before moving ahead to a demonstration reactor. A major assumption is that ITER will be successful in reaching its major goals and objectives. The Pathways study will identify the R&D areas that can be explored using existing devices and simulation facilities, and will provide cost/performance attributes of possible new major facilities that may be required. The design team will interact with leaders of the research community and DOE in defining possible projects for FY 2010 and beyond.

In addition, a series of studies will be initiated in FY 2009 within the research community to identify critical scientific issues and missions for the next stage in the U.S. fusion research program in the ITER era. Building off recent community and FESAC studies, this effort will concentrate on defining specific scientific issues to address and possible approaches to be taken to address them. The long-term objective is to identify potential initiatives and facilities that may be pursued at the pre-conceptual level.

	FY 2007	FY 2008	FY 2009
Materials Research	**4,679**	**5,800**	**4,791**

Materials Research remains the key element in establishing the scientific foundations for safe and environmentally attractive uses of fusion as well as providing solutions for materials issues faced by other parts of the FES program. The FY 2009 request will maintain a highly beneficial Materials Research program that addresses material needs for nearer and longer term fusion devices. The funding will be used for both modeling and experimental activities aimed at the science of materials behavior in fusion environments, including research on candidate materials for the structural elements of fusion chambers. Two cost-shared international collaborations (DOE/JAEA and TITAN) focusing on irradiation testing of candidate fusion materials in U.S. facilities will continue.

	FY 2007	FY 2008	FY 2009
Total, Enabling R&D	**20,754**	**21,791**	**22,715**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Engineering Research	
▪ **Plasma Technology**	
The decrease will slightly reduce the level of effort in the blanket and plasmas materials interaction programs.	-40
▪ **Advanced Design**	
The increase will support a series of new studies to identify critical scientific issues and missions for the next stage in the U.S. fusion research program in the ITER era.	+1,973
Total, Engineering Research	+1,973

	FY 2009 vs. FY 2008 ($000)
Materials Research	
The decrease will reduce the level of effort in the experimental activities reflecting a redirection of resources to higher priorities.	-1,009
Total Funding Change, Enabling R&D	**+924**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
General Plant Projects	3,860	1,587	1,968
Capital Equipment	64,857	20,099	231,013
Total, Capital Operating Expenses	68,717	21,686	232,981

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

(dollars in thousands)

	Total Estimated Cost (TEC)	Other Project Costs (OPC)	Total Project Cost (TPC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Completion Date
NCSX, PPPL	142,430[a]	9,570	152,000[a]	58,337	15,822	15,900	19,560	FY 2012[a]
U.S. Contributions to ITER, Cadarache, France	TBD	TBD	1,450,000–2,200,000[b]	15,866	42,000	—	208,500[b]	FY 2014–FY 2017[b]
Total, Major Items of Equipment					57,822	15,900	228,060	

[a] The NCSX TEC, TPC, and FY 2009 funding level and completion date reflect the estimated rebaseline.
[b] Funding is for the fourth year of the project, U.S. Contributions to ITER. The TPC and completion schedule ranges were approved at CD-1 in December 2007. The TPC and completion schedule performance baselines will be established at CD-2, planned for FY 2009-2010.

Science Laboratories Infrastructure

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Science Laboratories Infrastructure					
Infrastructure Support	12,947	15,427	-140[a]	15,287	21,308
Construction	29,039	50,029	+1,545[ab]	51,574	88,952
Subtotal, Science Laboratories Infrastructure	41,986	65,456	+1,405[ab]	66,861	110,260

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007"

Mission

The mission of the Science Laboratories Infrastructure (SLI) program is to support Department of Energy research missions at the ten Office of Science (SC) laboratories and the Oak Ridge Institute for Science and Education (ORISE) by funding line item construction, general plant projects, and cleanup and removal of excess facilities to maintain the general purpose infrastructure. The program also supports SC stewardship responsibilities for over 24,000 acres of the Oak Ridge Reservation (ORR) and the Federal facilities in the town of Oak Ridge, and provides Payment in Lieu of Taxes (PILT) to local communities around ANL, BNL, and ORNL.

Significant Program Shifts

The SLI program structure has been revised to group all operations activities under one Infrastructure Support subprogram. These activities include PILT at ANL and BNL, Excess Facilities Disposition (EFD) and Oak Ridge Landlord (ORO).

Infrastructure Modernization Initiative

SLI has proposed an Infrastructure Modernization Initiative to modernize the general purpose infrastructure at SC laboratories. The initiative focuses on increased funding for line item construction. The goals of the initiative are that, by FY 2018, the SC laboratories will have facilities and infrastructure that:

- Offer a safer, healthier and more secure work environment for employees and visitors;
- Have improved mission readiness;
- Are more efficient to operate and maintain, with a minimal deferred maintenance backlog;
- Meet or exceed DOE sustainability goals;

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[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.
[b] Includes $2,000,000 from prior year balances to support the Modernization of Laboratory Facilities project at ORNL, as directed in the Conference Report for the Energy and Water Development and Related Agencies Appropriations Act, 2008.

- Support worker productivity and facilitate effective interaction with colleagues; and
- Provide a satisfactory work environment worthy of world-class scientific institutions and able to help attract and retain high-quality scientific staff.

The FY 2007 new project start, Modernization of Building 4500N Wing 4, Phase I, at ORNL, has been cancelled and its FY 2007 and FY 2008 funding is redirected to a new FY 2008 project entitled Modernization of Laboratory Facilities (MLF) at ORNL as directed in the Conference Report for the Energy and Water Development and Related Agencies Appropriations Act, 2008. This new project will be the first project under SC's Infrastructure Modernization Initiative.

Construction funding increases to fund the three new FY 2009 construction projects which are part of the proposed SC Infrastructure Modernization Initiative. These are: Interdisciplinary Science Building, Phase I, project at BNL; the Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, project at LBNL; and the Technology and Engineering Development Facility project at TJNAF.

The additional funding for the SC Infrastructure Modernization Initiative in FY 2009 will be provided largely by the permanent transfer of $32,856,000 formerly used for landlord General Plant Projects (GPP) at SC multiprogram laboratories (Argonne National Laboratory [ANL], Brookhaven National Laboratory [BNL], Lawrence Berkeley National Laboratory [LBNL], Oak Ridge National Laboratory [ORNL], Pacific Northwest National Laboratory [PNNL], and Stanford Linear Accelerator Center [SLAC]) to SLI line item funding. These funds have been transferred to SLI from the following programs: High Energy Physics—$4,535,000, Basic Energy Sciences—$11,784,000, Biological and Environmental Research—$5,000,000, Nuclear Physics—$7,537,000, and Advanced Scientific Computing Research—$4,000,000. Those general purpose projects previously funded with SC program budget (landlord) GPP will now be funded with Institutional GPP (IGPP). IGPP, described in DOE Order 430.1, Real Property Asset Management, is funded from laboratory overhead at multiprogram laboratories. Thus, all programs funding work at a site will contribute to the general purpose infrastructure at that site. The expectation placed on the laboratories is that they will fund IGPP at or above their previous GPP levels. SC expects the laboratories to pay the IGPP from overhead without significant change to overhead rates based on two factors: expected growth in overall laboratory funding due to the American Competitiveness Initiative and efficiencies provided by the initiative itself in reduced operation and maintenance costs, reduced footprint, and higher facility utilization.

Proposals for Infrastructure Modernization Initiative projects have been submitted by each laboratory and have been evaluated collaboratively by a group composed of SC Site Managers, laboratory Chief Operating Officers, and the SC Chief Operating Officer. The projects have been evaluated against established criteria pertaining to their suitability of funding under the Initiative (screening criteria) and criteria pertaining to project priority across all laboratories (prioritization criteria). Based on this evaluation, selected projects have been included in the FY 2009 request. All projects will meet DOE requirements for energy efficiency optimization and sustainable environmental stewardship. SLI is developing measures for tracking the progress of the Infrastructure Modernization Initiative in improving mission readiness; operational reliability and safety; and reducing the footprint, deferred maintenance, and the average age of facilities.

Funding for small Excess Facilities Disposition (EFD) projects will be discontinued in FY 2009 because projects funded under the Infrastructure Modernization Initiative will, in many cases, include funds for removal of aged and outmoded facilities that are being replaced by new ones. Small decontamination and decommissioning (D&D) projects can also be funded with laboratory overhead. SC is working with the Office of Environmental Management to assure that the backlog of large contaminated facilities not addressed via the Modernization Initiative or laboratory overhead funds is properly dispositioned.

Infrastructure Support

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Infrastructure Support			
Payment in Lieu of Taxes	1,520	1,506	1,385
Excess Facilities Disposition	6,348	8,748	14,844
Oak Ridge Landlord	5,079	5,033	5,079
Total, Infrastructure Support	12,947	15,287	21,308

Description

The Infrastructure Support subprogram supports the SC mission by providing funding for Payment in Lieu of Taxes (PILT) to communities around ANL, BNL and ORNL, removal of excess facilities at SC sites to reduce long-term costs and liabilities, and activities to maintain continuity of operations at the Oak Ridge Reservation (ORR) and the Oak Ridge Service Center (including PILT for communities around ORNL).

Supporting Information

General purpose and site-wide infrastructure includes administrative, research laboratory, user support and testing space, as well as cafeterias, power plants, fire stations, electrical, gas and other utility distribution systems, sanitary sewers, roads, and other associated structures.

The ten SC research laboratories, and ORISE, together have over 1,500 operational buildings and real property trailers, with 19.9 million gross square feet of space. Over 8,500 employees and users of SC research facilities are housed in wooden buildings, trailers or buildings more than 50 years old. The average age of active SC buildings is 35 years. Nine million square feet are 40 years old or older, including 5 million square feet that are over 50 years old.

As required by DOE Order 430.1B, Real Property Asset Management, SC laboratories have prepared Ten Year Site Plans (TYSPs). These plans identify facility and infrastructure investments needed for real property assets to support mission requirements. The 2007 TYSPs are available at: http://www.sc.doe.gov/sc-80/sc-82/tysp.shtml.

The TYSPs have identified a number of infrastructure needs that are primarily attributable to:

- the age of the facilities;
- the use of wood and other non-permanent building materials in the original construction of the laboratories in the 1940’s and 1950’s;
- changing research needs that require:
  - different kinds of facilities (e.g., nuclear facilities, such as hot cells, are in lower demand, while facilities that foster interaction and team-based research are in higher demand) and
  - higher quality facilities (e.g., reduced vibration and temperature variability, better air quality and increased power capability for computers and other electronic equipment);

- obsolescence of existing building systems and components, and changing technology (e.g., digital controls for heating and ventilation systems, fire alarms and security);
- need for improved reliability of utility operations to support the large number of researchers at SC user facilities; and
- changing environmental, safety and health regulations, and security needs.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Payment in Lieu of Taxes (PILT)	**1,520**	**1,506**	**1,385**

Provides PILT to support assistance requirements for communities around Argonne National Laboratory and Brookhaven National Laboratory. PILT payments are negotiated between the Department and local governments based on land values and tax rates.

Excess Facilities Disposition (EFD)	**6,348**	**8,748**	**14,844**

Funding for Excess Facilities Disposition supports removal of excess facilities at SC sites to reduce long-term costs and liabilities. The EFD funding also supports cleanup of facilities for reuse when such reuse is economical and provides needed functionality.

SC is responsible for disposal, by demolition or cleanup for reuse, of facilities at its sites that are not specifically assigned to another DOE Program Office, regardless of which Office in DOE, or its predecessor agencies, may have been responsible for their construction and operation. This includes both those facilities currently awaiting disposal, as well as those which will need to be disposed of in the future, but are still in use. The most recent estimate of the projected cost for disposal of these facilities is expected to exceed $400M.

Funding for small projects ($5M or less) will be discontinued in FY 2009 because projects funded under the Infrastructure Modernization Initiative will, in many cases, include funds for removal of aged and outmoded facilities that are being replaced by new ones. Small decontamination and decommissioning (D&D) projects can also be funded with laboratory overhead. SC is working with the Office of Environmental Management to assure that the backlog of large nuclear related D&D projects which comprise the bulk of the backlog is properly dispositioned.

FY 2007 funding supported the projects listed below, allowing the cleanup/removal of an estimated 9,000 square feet of space:

- ANL ($500,000) – Partial Demolitions of Building 306, Waste Management Operations Facility, A, B, C and Trailer 5, and Cleanup of Building 205, Chemical Technology, Room A-141 (1,600 square feet)
- BNL ($697,000) – Continued Stabilization of Building 650, Hot Laundry Facility, and Demolition of Building 650A, Storage (1,246 square feet)

LBNL ($3,850,000) – Continued Demolition of Building 51 and the Bevatron ($2,450,000), and Removal of the SuperHILAC ($1,400,000)

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

- ORISE ($117,000) – Demolition of Bldg. SC-2, Isotope Laboratory, SC-4, Poultry Nutrition Bldg., Bldg. SC-5, Large Animal Containment Facility, and Bldg. 26, Swine Holding Facility (6,593 square feet)
- ORNL ($1,069,000) – Demolition of Building 2010, ORNL Cafeteria

FY 2007 funding also included $115,000 to conduct External Independent Reviews (EIRs) of SLI construction projects.

FY 2008 funding will support the projects listed below, allowing the cleanup/removal of an estimated 18,000 square feet of space:

- ANL ($389,000) – Demolition of Building 40 Calibration Lab (4,896 square feet)
- LBNL ($8,145,000) – Continued Demolition of Building 51 and the Bevatron ($6,145,000), and Removal of the SuperHILAC ($2,000,000)
- ORNL ($206,000) – Continued demolition of Building 2010, ORNL Cafeteria (12,946 square feet)
- Unallocated ($8,000) – To be allocated to other priority projects in FY 2008.

In FY 2009, the total of $14,844,000 of EFD funding will be provided to continue D&D of Building 51 and the Bevatron at LBNL.

The total cost of the Building 51 and Bevatron D&D project is estimated to range from $65,000,000 to $75,300,000. The project is scheduled to be completed by FY 2011. The project eliminates a legacy accelerator which ceased operation in 1993 freeing up approximately 3 acres of land—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 120,000 square feet of laboratory and office space in offsite buildings at a current cost of approximately $6.1 million per year. Continued reliance on an aged and decaying physical plant impedes research, reduces productivity, and makes recruitment and retention of top-quality scientists and engineers more difficult.

	FY 2007	FY 2008	FY 2009
Oak Ridge Landlord	**5,079**	**5,033**	**5,079**

This funding supports landlord responsibilities, including infrastructure for the 24,000 acres of the Oak Ridge Reservation outside of the Y-12 plant, ORNL and the East Tennessee Technology Park, and DOE facilities in the town of Oak Ridge. The supported activities include maintenance of roads, grounds and other infrastructure, support and improvement of environmental protection, safety and health, payment of PILT to Oak Ridge communities, and other needs related to landlord responsibilities. These activities maintain continuity of operations at the Oak Ridge Reservation and the DOE facilities in Oak Ridge, and minimize interruptions due to infrastructure and/or other systems failures.

	FY 2007	FY 2008	FY 2009
▪ **Roads, Grounds and Other Infrastructure Support and Improvements**	**2,051**	**2,254**	**2,401**

Maintenance of roads, grounds, and other infrastructure.

	FY 2007	FY 2008	FY 2009
▪ **General Plant Projects (GPP)**	**200**	**100**	**100**

Major road repair at the Oak Ridge Reservation.

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
▪ **Oak Ridge Payment in Lieu of Taxes (PILT)**	**2,550**	**2,550**	**2,550**

Includes PILT to the City of Oak Ridge, and Anderson and Roane Counties.

▪ **Reservation Technical Support**	**278**	**129**	**28**

Beginning in FY 2009, the meteorological monitoring system, the public warning siren system, Oak Ridge Reservation command media, and records management will be paid for by the Oak Ridge Reservation occupants. Mapping and Real Estate activities will continue to be supported.

Total, Infrastructure Support	**12,947**	**15,287**	**21,308**

Explanation of Change

	FY 2009 vs. FY 2008 ($000)
Infrastructure Support	
Payment in Lieu of Taxes (PILT)	
PILT funding is decreased due to lower than projected actual payments.	-121
Excess Facilities Disposition (EFD)	
The increase will support the demolition of Building 51 and the Bevatron at LBNL.	+6,096
Oak Ridge Landlord	
Maintenance of roads, grounds, and other infrastructure is increased ($147,000). Support for the meteorological monitoring system, the public warning siren system, ORR command media, and records management is decreased (-$101,000).	+46
Total Funding Change, Infrastructure Support	**+6,021**

Construction

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Construction			
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II (LBNL)	—	—	12,495
Interdisciplinary Science Building, Phase I (BNL)	—	—	8,240
Technology and Engineering Development Facility (TJNAF)	—	—	3,700
Modernization of Laboratory Facilities (ORNL)	—	9,329	14,103
Physical Sciences Facility (PNNL)	10,000	24,773	41,155
Science Laboratories Infrastructure Project (Various)	19,039	17,472	9,259
Total, Construction	29,039	51,574	88,952

Description

The SLI Construction subprogram funds line item construction projects to maintain and enhance the general purpose infrastructure at SC laboratories.

All candidate construction projects proposed for funding by each laboratory are evaluated collaboratively by SC Site Managers, laboratory Chief Operating Officers, and the SC Chief Operating Officer. The projects are evaluated against established criteria pertaining to their suitability of funding under the Initiative (screening criteria) and criteria pertaining to project priority across all laboratories (prioritization criteria). Based on this evaluation, selected projects are recommended for funding by SC. The projects identified in this budget reflect this process. All SLI projects will meet DOE requirements for energy efficiency optimization and sustainable environmental stewardship. The SLI program is developing measures for tracking the progress of the Infrastructure Modernization Initiative in improving mission readiness, operational reliability and safety, and reducing footprint, deferred maintenance and the average age of facilities.

The SLI Construction subprogram strives to ensure that the funded subprojects are managed effectively and completed within the established cost, scope, and schedule baselines. Performance is measured by the number of all SLI subprojects completed within the approved baseline for cost, scope (within 10%), and schedule (within six months). For example, in FY 2007, the BNL Research Support Building subproject was completed within its cost, scope, and schedule baseline.

The FY 2009 request provides final construction funding for two subprojects, continued construction funding for the Physical Sciences Facility at PNNL and the Modernization of Laboratory Facilities at ORNL (FY 2008 start), initial project engineering and design (PED) funding for three new FY 2009 starts, and initial construction funding for one of those new starts.

The one new FY 2008 start and the three new FY 2009 starts are the initial projects under the Infrastructure Modernization Initiative. These four projects are estimated to reduce deferred maintenance by $44.2 million and thereby improve the Asset Condition Index of their laboratories. Three of the projects will also replace existing space. A summary of the estimated improvements based on the conceptual plans for these projects is shown in the table below. These estimates are subject to change.

	Space Removed (square feet)	Deferred Maintenance Reduction		Asset Condition Index	
		($000)	% of Total DM	Before	After
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II at LBNL	43,060	6,100	11%	93%	94%
Interdisciplinary Science Building, Phase I at BNL	100,000-120,000	2,300	2%	94%	94%
Technology and Engineering Development Facility at TJNAF	22,000	4,300	46%	94%	98%
Modernization of Laboratory Facilities at ORNL	—	31,500	17%	89%	91%

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, at LBNL (09-SC-72)	**—**	**—**	**12,495**

This project will remedy high seismic life-safety risks in general-purpose research facilities and lab-wide resource buildings. It will replace three seismically "very poor" and "poor" (University of California classification) buildings and five failing trailers that cannot be cost-effectively upgraded (43,060 square feet) with one new approximately 43,000 square feet general-purpose laboratory/office building. Construction of the new building will allow LBNL to vacate 36,000 square feet of off-site leased space currently costing an estimated $1.9 million per year. This project will also seismically upgrade Building 85, the site-wide Hazardous Waste Handling Facility, and modernize Building 74, a 45,382 square feet general-purpose laboratory/office building. Demolition costs are included in the project.

Interdisciplinary Science Building, Phase I, at BNL (09-SC-73)	**—**	**—**	**8,240**

This project will replace up to 5 wooden buildings (average age of 68 years) and 3 masonry buildings (average age of 64 years)—an area of 100,000 to 120,000 square feet - with a new building (87,000 to 93,000 square feet) with state-of-the-art laboratories, associated offices and support space. Energy-efficient heating, ventilation, and air-conditioning systems will be installed in the new building, which will support cutting edge experimentation and the operation of sensitive instrumentation. The general purpose and prep laboratories will have a flexible design to accommodate a wide array of research needs.

The support space will include "interaction areas" for informal discussions, a seminar room, and a lunch room.

The buildings that will be demolished by this project have been slated for near-term demolition, pending the availability of funds for their replacement. As such, the estimated value of deferred maintenance that

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

will be eliminated by this project (approximately $2,300,000) represents only the estimated cost to keep the buildings occupied, rather than the cost of maintaining them at a condition that would be satisfactory for long-term use.

Technology and Engineering Development Facility at TJNAF (09-SC-74)	**—**	**—**	**3,700**

This project will address infrastructure inadequacies to support the laboratory's current mission by renovating the 42-year-old Test Lab Building and correcting a critical shortage of space for technology and engineering. The project will renovate about 89,000 square feet in the Test Lab Building and remove over 10,000 square feet of inadequate and obsolete work space. These changes will provide efficient workflow, a safe and sustainable work environment, and functional efficiencies in areas such as clean rooms, chemistry facilities, high bay, and laboratories. The project will also construct a new building which will provide approximately 100,000 square feet of space to eliminate severe overcrowding and improve workflow and productivity by co-locating the engineering and technical functions currently spread across the Laboratory. Energy consumption in the new and rehabilitated building will be reduced by about 30%. This project will also fund the demolition of about 12,000 square feet of dilapidated trailers.

Modernization of Laboratory Facilities at ORNL (08-SC-71)	**—**	**9,329**	**14,103**

This project will construct a new chemical sciences and materials science laboratory that will provide 140,000 to 170,000 square feet of modern, 21st-century research laboratories, with associated space for offices for researchers, small-group conference rooms, and support functions. The new building will allow researchers to move from the 4500 Complex, allowing that space to later be renovated to support general office and support space using laboratory Institutional General Plant Projects (IGPP) funds.

This project will reduce deferred maintenance in laboratory support systems in the 4500 Complex by $31,500,000 because space previously used as laboratories will change to office and support space, and these systems will no longer be necessary. The phased renovation of the 4500 Complex and movement of staff are not funded as part of this project, but cannot be undertaken without it.

The FY 2008 funding for this project was transferred from the cancelled Modernization of Laboratory, Building 4500N, Wing 4, Phase I, at ORNL subproject (MEL-001-024).

Physical Sciences Facility at PNNL (07-SC-05)	**10,000**	**24,773**	**41,155**

This project will construct new laboratory and office space on the PNNL site north of Horn Rapids Road, and complete life extension upgrades to the 325 Building 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.

Science Laboratories Infrastructure Project (MEL-001)	**19,039**	**17,472**	**9,259**
▪ **Safety and Operational Reliability Improvements at SLAC (MEL-001-036)**	**5,770**	**—**	**—**

Funding for this subproject was completed in FY 2007.

	FY 2007	FY 2008	FY 2009
(dollars in thousands)			
▪ **Building Electrical Services Upgrade, Phase II, at ANL (MEL-001-049)**	**3,000**	**—**	**—**

As a result of reduced funding for construction in the FY 2008 Appropriation, the Building Electrical Services Upgrade, Phase II, subproject MEL-001-049 at ANL has been cancelled. This will allow the remaining two subprojects started in FY 2007, the Seismic Safety Upgrade of Buildings, Phase I, at LBNL, and the Renovate Science Laboratory, Phase I, at BNL to be fully funded and remain on schedule. The FY 2007 funding will be used to address the most critical electrical upgrades at ANL. The remaining scope of the subproject will be funded via laboratory overhead, if high priority, or via a future ANL modernization project.

	FY 2007	FY 2008	FY 2009
▪ **Renovate Science Laboratory, Phase I, at BNL (MEL-001-050)**	**3,158**	**8,200**	**6,642**

This subproject will upgrade and rehabilitate existing obsolete and unsuitable laboratory facilities into modern, efficient facilities compatible with world-class scientific research.

	FY 2007	FY 2008	FY 2009
▪ **Seismic Safety Upgrade of Buildings, Phase I, at LBNL (MEL-001-047)**	**5,111**	**9,272**	**2,617**

This subproject will address the seismic vulnerability of laboratory buildings where high life-safety risks have been identified.

	FY 2007	FY 2008	FY 2009
▪ **Modernization of Laboratory, Building 4500N, Wing 4, Phase I, at ORNL (MEL-001-024)**	**2,000**	**—**	**—**

This project has been cancelled and replaced by the Modernization of Laboratory Facilities project. Accordingly, the $2,000,000 of PED funding requested in FY 2007, and the $7,329,000 of construction funding requested in FY 2008 for this project was redirected to the design and construction of the Modernization of Laboratory Facilities project, and no FY 2009 funding is requested for this project.

	FY 2007	FY 2008	FY 2009
Total, Construction	**29,039**	**51,574**	**88,952**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II, at LBNL (09-SC-72)	
Initial PED ($+8,680,000) and construction ($+3,815,000) funding is provided for the project which will remedy high seismic life-safety risks in general purpose facilities at LBNL.	+12,495

	FY 2009 vs. FY 2008 ($000)
Interdisciplinary Science Building, Phase I, at BNL (09-SC-73)	
Initial PED funding is provided for design of a new Interdisciplinary Science building at BNL.	+8,240
Technology and Engineering Development Facility at TJNAF (09-SC-74)	
Initial PED funding is provided for design of a new building and renovation of an existing building at TJNAF.	+3,700
Modernization of Laboratory Facilities at ORNL (08-SC-71)	
Increased construction funding is provided per schedule for the new laboratory replacement building at ORNL.	+4,774
Physical Sciences Facility at PNNL (07-SC-05)	
Continued funding for the Physical Sciences Facility (PSF) at Pacific Northwest National Laboratory (PNNL) is provided per project schedule.	+16,382
MEL-001, Science Laboratories Infrastructure Project	
▪ **Renovate Science Laboratory, Phase I, at BNL (MEL-001-050)**	
Final funding to revitalize and modernize laboratories in two buildings at Brookhaven National Laboratory (BNL) is provided per project schedule.	-1,558
▪ **Seismic Safety Upgrade of Buildings, Phase I, at LBNL (MEL-001-047)**	
Final funding for the first phase of seismic and structural safety upgrades at Lawrence Berkeley National Laboratory (LBNL) is provided per project schedule.	-6,655
Total, MEL-001, Science Laboratories Infrastructure Project	**-8,213**
Total, Construction	**+37,378**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
General Plant Projects	200	100	100

Construction Projects

(dollars in thousands)

	Other Project Costs (OPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2007	FY 2008	FY 2009	Unapprop. Balance
09-SC-72, Seismic Life-Safety, Modernization, and Replacement of General Purpose Buildings, Phase II (LBNL), PED and Construction	N/A	91,900–96,000	—	—	—	12,495[a]	79,405–83,505
09-SC-73, Interdisciplinary Science Building, Phase I (BNL), PED	N/A	8,240	—	—	—	8,240[b]	—
09-SC-74, Technology and Engineering Development Facility (TJNAF), PED	N/A	3,700	—	—	—	3,700[c]	—
08-SC-71, Modernization of Laboratory Facilities (ORNL), PED and Construction	N/A	90,000–95,000	—	—	9,329[d]	14,103[d]	66,568–71,568
07-SC-04, Project Engineering Design, Various Locations		8,908	—	8,908	—	—	—
07-SC-05, Physical Sciences Facility (PNNL)	N/A	98,444	10,896	10,000	24,773	41,155	11,620
MEL-001, Science Laboratories Infrastructure Project	N/A	N/A	N/A	10,131	17,472	9,259	N/A
Total, Construction				29,039	51,574	88,952	

[a] PED of $8,680,000 is requested in FY 2009 along with $3,815,000 of construction.
[b] PED only requested in FY 2009. Preliminary estimated TEC range is $61,300,000–$66,300,000.
[c] PED only requested in FY 2009. Preliminary estimated TEC range is $66,000,000–$72,200,000.
[d] $8,700,000 of FY 2008 funding is for PED. The remaining $629,000 of FY 2008 funding and all of the funding requested for FY 2009 is to be used for construction. Preliminary estimated TEC range is $90,000,000–$95,000,000.

Science Program Direction

Funding Profile by Category

(dollars in thousands, whole FTEs)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Headquarters (HQ)					
Salaries and Benefits	46,189	53,409	-1,633[a]	51,776	54,847
Travel	2,069	2,500	—	2,500	3,560
Support Services	12,038	10,262	—	10,262	12,261
Other Related Expenses	9,829	10,048	—	10,048	12,178
Total, Headquarters	70,125[b]	76,219	-1,633[a]	74,586[b]	82,846
Full Time Equivalents	307[b]	386	—	386[b]	351
Office of Scientific and Technical Information (OSTI)					
Salaries and Benefits	—	—	—	—	6,571
Travel	—	—	—	—	84
Support Services	—	—	—	—	1,207
Other Related Expenses	—	—	—	—	1,054
Total, Office of Scientific and Technical Information	—[b]	—	—	—[b]	8,916
Full Time Equivalents	—[b]	—	—	—[b]	57
Field Offices					
Chicago Office (CH)					
Salaries and Benefits	22,788	22,750	—	22,750	26,535
Travel	405	382	—	382	425
Support Services	2,026	1,905	—	1,905	2,282
Other Related Expenses	2,968	1,023	—	1,023	2,121
Total, Chicago Office	28,187	26,060	—	26,060	31,363
Full Time Equivalents	191	187	—	187	207

[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.

[b] Starting in FY 2009, OSTI is proposed as a separate line. In FY 2007 and FY 2008, OSTI funding is included within HQ funding. FY 2007 OSTI amounts are $8,600,000 and 54 FTEs, and non-OSTI HQ amounts are $61,525,000 and 253 FTEs. FY 2008 Current Appropriation OSTI amounts are $8,684,000 and 58 FTEs and non-OSTI HQ amounts are $65,902,000 and 328 FTEs.

	(dollars in thousands, whole FTEs)				
	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Oak Ridge Office (OR)					
Salaries and Benefits	29,796	30,675	—	30,675	32,050
Travel	621	492	—	492	695
Support Services	8,004	6,194	—	6,194	6,484
Other Related Expenses	5,163	6,089	—	6,089	6,112
Total, Oak Ridge Office	43,584	43,450	—	43,450	45,341
Full Time Equivalents	294	282	—	282	281
Ames Site Office (AMSO)					
Salaries and Benefits	432	465	—	465	479
Travel	19	25	—	25	25
Support Services	25	30	—	30	33
Other Related Expenses	43	35	—	35	39
Total, Ames Site Office	519	555	—	555	576
Full Time Equivalents	3	3	—	3	3
Argonne Site Office (ASO)					
Salaries and Benefits	3,116	3,522	—	3,522	3,621
Travel	34	41	—	41	47
Support Services	221	262	—	262	292
Other Related Expenses	318	300	—	300	329
Total, Argonne Site Office	3,689	4,125	—	4,125	4,289
Full Time Equivalents	23	25	—	25	25
Berkeley Site Office (BSO)					
Salaries and Benefits	3,251	3,542	—	3,542	3,898
Travel	65	105	—	105	107
Support Services	663	412	—	412	427
Other Related Expenses	215	335	—	335	248
Total, Berkeley Site Office	4,194	4,394	—	4,394	4,680
Full Time Equivalents	20	25	—	25	26

(dollars in thousands, whole FTEs)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Brookhaven Site Office (BHSO)					
Salaries and Benefits	3,200	3,771	—	3,771	3,888
Travel	61	62	—	62	71
Support Services	1	180	—	180	352
Other Related Expenses	485	221	—	221	218
Total, Brookhaven Site Office	3,747	4,234	—	4,234	4,529
Full Time Equivalents	22	27	—	27	27
Fermi Site Office (FSO)					
Salaries and Benefits	1,937	2,197	—	2,197	2,240
Travel	38	53	—	53	54
Support Services	127	146	—	146	171
Other Related Expenses	160	100	—	100	105
Total, Fermi Site Office	2,262	2,496	—	2,496	2,570
Full Time Equivalents	14	15	—	15	15
New Brunswick Laboratory (NBL)[a]					
Salaries and Benefits	—	3,956	—	3,956	4,094
Travel	—	73	—	73	73
Support Services	—	274	—	274	274
Other Related Expenses	—	2,341	—	2,341	2,341
Total, New Brunswick Laboratory	—	6,644	—	6,644	6,782
Full Time Equivalents	—	35	—	35	35

[a] Responsibility for the New Brunswick Laboratory was transferred in FY 2008 to the Office of Science from the former Office of Security and Safety Performance Assurance.

(dollars in thousands, whole FTEs)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Pacific Northwest Site Office (PNSO)					
Salaries and Benefits	4,285	4,559	—	4,559	4,804
Travel	110	63	—	63	65
Support Services	184	104	—	104	107
Other Related Expenses	257	327	—	327	642
Total, Pacific Northwest Site Office	4,836	5,053	—	5,053	5,618
Full Time Equivalents	34	36	—	36	36
Princeton Site Office (PSO)					
Salaries and Benefits	1,597	1,640	—	1,640	1,691
Travel	41	39	—	39	40
Support Services	4	10	—	10	10
Other Related Expenses	11	70	—	70	72
Total, Princeton Site Office	1,653	1,759	—	1,759	1,813
Full Time Equivalents	12	12	—	12	12
Stanford Site Office (SSO)					
Salaries and Benefits	1,659	2,038	—	2,038	2,101
Travel	38	55	—	55	61
Support Services	409	346	—	346	402
Other Related Expenses	17	112	—	112	61
Total, Stanford Site Office	2,123	2,551	—	2,551	2,625
Full Time Equivalents	12	13	—	13	13
Thomas Jefferson Site Office (TJSO)					
Salaries and Benefits	1,438	1,671	—	1,671	1,737
Travel	39	73	—	73	75
Support Services	52	91	—	91	115
Other Related Expenses	21	37	—	37	38
Total, Thomas Jefferson Site Office	1,550	1,872	—	1,872	1,965
Full Time Equivalents	10	12	—	12	12

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
	(dollars in thousands, whole FTEs)				
Total Field Offices					
Salaries and Benefits	73,499	80,786	—	80,786	87,138
Travel	1,471	1,463	—	1,463	1,738
Support Services	11,716	9,954	—	9,954	10,949
Other Related Expenses	9,658	10,990	—	10,990	12,326
Total, Field Offices	96,344	103,193	—	103,193	112,151
Full Time Equivalents	635	672	—	672	692
Total Science Program Direction					
Salaries and Benefits	119,688	134,195	-1,633[a]	132,562	148,556
Travel	3,540	3,963	—	3,963	5,382
Support Services	23,754	20,216	—	20,216	24,417
Other Related Expenses	19,487	21,038	—	21,038	25,558
Total, Science Program Direction	166,469	179,412	-1,633[a]	177,779	203,913
Full Time Equivalents	942	1,058	—	1,058	1,100

Mission

The Science Program Direction (SCPD) mission is to provide a skilled and highly motivated Federal workforce 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.

Description

The Headquarters (HQ) Federal staff is responsible for SC-wide issues, operational policy, scientific program development, and management functions supporting a broad spectrum of scientific disciplines and program offices. These disciplines include Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, and Nuclear Physics, and also includes activities conducted by the Workforce Development for Teachers and Scientists program office. Additionally, support is included for management of workforce program direction and infrastructure through policy, technical, and administrative support staff responsible for budget and planning; general administration; information technology (IT); infrastructure management; construction management; Safeguards and Security (S&S); and Environment, Safety, and Health (ES&H) within the framework set by the Department.

SCPD includes funding for the Office of Scientific and Technical Information (OSTI), which collects, preserves, and disseminates research and development (R&D) information produced by Department of Energy (DOE)-sponsored research for use by DOE, the scientific community, academia, U.S. industry,

[a] Reflects a reduction for the 0.91% rescission in P.L. 110–161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.

and the public to expand the knowledge base of science and technology. 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. Accelerating the dissemination of DOE's R&D information or "knowledge" serves to accelerate the pace of scientific progress itself. OSTI is responsible for the development and operation of DOE's leading e-Government (e-Gov) systems such as the Information Bridge, Energy Citations Database, and the E-Print Network, which are all integrated under the Science Accelerator. OSTI also developed and hosts the interagency e-Gov system Science.gov, which uses breakthrough technology for simultaneously searching across more than 50 million pages in 30 federal databases involving 13 different federal science agencies. Internationally, DOE (representing the United States), through OSTI's partnership with the British Library, used the same federated searching technology to open a web-based global gateway to science information, covering 24 portals and databases from 17 countries. The gateway, WorldWideScience.org, provides citizens, researchers and anyone interested in science the capability to search science portals not typically accessible through commercial search engine technology. U.S. access to international research information is key to American competitiveness in science and technology. Although the majority of DOE's R&D output is open to the scientific community, a sizable share is classified or sensitive, and OSTI's responsibilities are to ensure protection and limited, appropriate access in support of DOE's national security mission.

Field personnel are responsible and directly accountable for implementing the SC program within the framework established by HQ policy and guidance. Site Office personnel are responsible for the day-to-day 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. As of FY 2008, SC also supports the New Brunswick Laboratory, a government-owned, government-operated center of excellence in the measurement science of nuclear materials. In addition, the Integrated Support Center, operated in partnership by the Chicago (CH) and Oak Ridge (OR) Operations office personnel, provides best-in-class business, administrative, and specialized technical support across the entire SC enterprise and to other DOE programs. Centers of Excellence include Grants Management and Intellectual Property Law at CH. Workforce operations in the field include financial stewardship, Human Resources (HR), grants and contracts, labor relations, security, legal counsel, public affairs, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, and information systems development and support.

SC is continuing to work on its Human Capital Management (HCM) Plan covering all SC employees and locations. The HCM Plan is designed to ensure that the current and future SC workforce is in place to accomplish SC mission requirements. SC is working to attract and retain a capable and proficient workforce to ensure existing continuity and the future of its basic research programs. This is a dilemma faced by many agencies, but is particularly acute and problematic for SC given the high degree of specialized knowledge and technical qualifications required of its workforce. Within SC, procedures and processes are being developed that will provide a consistent methodology for workforce planning across the SC enterprise that also recognizes site-specific requirements. This methodology should:

- facilitate understanding of the SC skills mix at HQ and in the Field;
- identify positions for succession planning;
- develop a workforce pipeline for critical occupations at all levels of the organization in HQ and the Field, by using innovative and strategically deployed recruitment, retention, and developmental tools;

- reinforce a results-oriented performance culture, placing significant emphasis on and linking of performance, pay, and expectations; and
- use the appropriate customer service standards, the results of the Office of Personnel Management (OPM) employee satisfaction survey and the OPM hiring timelines as measures to continually improve our recruitment strategies and timelines.

Program Direction is grouped into four major categories:

- Salaries and benefits for FY 2009 provide for 351 Federal full time equivalents (FTEs) at HQ (employees based in Germantown, Maryland and Washington, DC) and 749 Federal FTEs at OSTI and the Site/Field offices located throughout the United States. In addition, funding is provided for other pay-related costs such as the government's contribution for employee health insurance and retirement, workers' compensation payments to the Department of Labor, transit subsidies, and incentive awards.
- Travel includes all costs of transportation, subsistence, and incidental travel expenses of SC's Federal employees and Advisory Committee members in accordance with Federal Travel Regulations. This also includes travel costs associated with permanent change of station (PCS).
- Support services include both technical expertise and general administrative services and activities. Technical support services include development of specifications, system definition, system review and reliability analyses; and test and evaluation, surveys or reviews. Management support services include, but are not limited to, directives management studies; automated data processing; training and education; analyses of Departmental management processes; and any other reports or analyses directed toward improving the effectiveness, efficiency and economy of management and general administrative services.
- Other related expenses provide funding for fixed requirements associated with rent, utilities, and telecommunications. Requirements such as building and grounds maintenance, computer/video maintenance and support, printing and graphics, copier leases, site-wide health care units, equipment, and storage of household goods and the buying/selling of homes in conjunction with directed PCS are also included. A Working Capital Fund (WCF) established at HQ to which SC contributes, allocates the costs of common Departmental administrative services to the recipient organizations. Activities supported by the WCF include telephone services, postage, supplies, photocopying, building occupancy, Payroll Processing, contract closeouts, corporate training services, Project Management Career Development Program, Corporate Human Resource Information System, Standard Accounting and Reporting System (STARS), and the Strategic Integrated Procurement Enterprise System (STRIPES).

The FY 2009 SCPD budget request supports salaries, benefits, travel, training, and associated support expenses to include 49 new FTEs requested in the FY 2009 budget as well as 58 new FTEs requested in the FY 2007 and FY 2008 budgets. These additional FTEs and funding are required to address staffing and travel concerns identified by numerous Committee of Visitors (COV) reports over the last several fiscal years and to support a significantly increased SC program budget.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Salaries and Benefits	**119,688**	**132,562**	**148,556**

In FY 2009, salaries and benefits are requested for 1,100 FTEs, an increase of 42 FTEs comprising 21 additional Program Managers and support staff requested across the SC HQ Program Offices to ensure the necessary resources and infrastructure exist to facilitate sound scientific program development and management of a significantly increased SC research investment and to also address specific staffing concerns identified by recent COV reports; 20 FTEs at the CH Office to ensure acquisition, financial, and other necessary infrastructure is in place to support a significantly increased SC R&D investment related to the American Competitiveness Initiative (ACI) over the next 5 years; 6 FTEs who manage the High Flux Isotope Reactor (HFIR) at the OR Office, will be transferred from the Office of Nuclear Energy (NE) to SC; 2 FTEs who manage the Isotope Program will be transferred from NE to SC-HQ; and an offsetting reduction of 7 FTEs across the Field complex achieved through attrition and workforce management incentives.

The FY 2009 salary and benefit request assumes a 2.9% pay raise in January 2009 and 4.7% escalation for personnel/pay related activities for benefits such as employee health and retirement. Strategically deployed recruitment, relocation, and retention bonuses will be employed corporately to attract and retain technically skilled and highly qualified employees.

Travel	**3,540**	**3,963**	**5,382**

Enables federal staff to effectively manage a broad spectrum of scientific disciplines and perform contractor oversight at geographically dispersed facilities to ensure implementation of DOE orders and regulatory requirements including process reviews, internal audits, compliance reviews, oversight of investigations, and administrative proceedings; and to attend numerous site, project, and program reviews; operational policy reviews and meetings; conferences; and training for skill maintenance and/or certification.

The request also includes travel expenses for over 150 members making up the 6 individual SC advisory committees. Committee membership primarily consists of representatives from universities, national laboratories, and industry and includes a diverse balance of disciplines, experiences, and geography. Each of the six advisory committees meets three to four 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.

The FY 2009 increase supports the additional program and support staff and specifically addresses travel funding concerns identified by recent COV reports.

Support Services	**23,754**	**20,216**	**24,417**

Provides for day-to-day operations, including mailroom services, travel processing, and administration of the Small Business Innovation Research program. Support is also provided for maintenance, operation, and cyber security management of SC-HQ and Field mission specific Information Management systems and infrastructure and SC-corporate Enterprise Architecture and Capital Planning Investment Control management. Supports energy research analysis, studies and activities relevant to DOE's energy and science missions, including: adaption of the Department of Defense's 6.1–6.7 stage gate to the needs of energy technology development for the non-government customer; design of decadal technology strategy surveys that can advise priorities, queuing, balance, and research portfolio

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

mix; and assessment of the information value of demonstration and deployment investments to markets and identification of appropriate metrics for measuring this impact. Provides accessibility of DOE's multi-billion dollar R&D program through e-Gov information systems managed and administered by OSTI and supports operations and maintenance of the Searchable Field Work Proposal (FWP) system, which will provide HQ and Field organizations a tool to search, evaluate, and monitor both legacy and current FWPs.

Training and education of federal staff, including continuing education, career development training and other initiatives, such as the Student Career Experience Program and the Student Temporary Employment Program, will continue to be supported.

Other areas of support include staffing 24-hour emergency communications centers, S&S services; grants and contract close-out activities, copy centers, directives coordination, and filing and retrieving records.

Other Related Expenses	**19,487**	**21,038**	**25,558**

Provides support in the Field for office space, telecommunications, utilities, building/equipment maintenance, supplies, other services, and equipment. Includes SC's contributions to the WCF for: common administrative services at HQ, such as rent and building operations, telecommunications, network connectivity, supplies/equipment, printing/graphics, copying, mail, contract closeout and purchase card surveillance; operation and maintenance of STARS and STRIPES; contractor support for the Payments Processing Center (PPC) at the OR Financial Service Center (ORFSC); and Office of Management and Budget (OMB) Circular A-123 reporting requirements support. In addition, WCF services assessed to and used by HQ, OSTI, and the Field include online training, Corporate Human Resource Information System (CHRIS), payroll processing and the Project Management Career Development Program (PMCDP). Also includes IT project management training; and e-Gov 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.

Funding responsibility of the Department's nation-wide PPC at the ORFSC is transferred from SC to the Department's WCF starting in FY 2009. Each Departmental organization will be assessed an equitable share of the PPC contractor support requirements. As the responsible program for OR, SC will continue to fund the salaries, benefits and related expenses of the federal staff providing oversight to the ORFSC and PPC.

Total, Science Program Direction	**166,469**	**177,779**	**203,913**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Salaries and Benefits	
Provides support for 1,100 FTEs, a net increase of 42 FTEs over FY 2008 that includes 21 additional Program Managers and support staff across the SC HQ program offices; 20 FTEs at the CH Office; 6 FTEs who manage HFIR at the OR Office, transferred from NE to SC; 2 FTEs who manage the Isotope Program transferred from NE to SC-HQ; and an offsetting reduction of 7 FTEs across the Field. This assumes a 2.9% pay raise for 2009; 4.7% escalation for personnel/pay related activities such as benefits for health insurance and retirement; and an increased cap for Senior Executive Service (SES) basic pay. Increase also provides full year salary and benefits costs associated with 58 FTEs requested in the FY 2007 and FY 2008 budgets but not planned to be hired until late FY 2008 or early FY 2009 due to the FY 2007 year-long continuing resolution and the reduced FY 2008 enacted budget.	+15,994
Travel	
Specifically, the increase will support the additional travel requirements related to an increased SC workforce and address SC-HQ program office travel concerns identified by COV reports. Includes 2.3% escalation for non-pay activities. Specifically the $1,419,000 increase over FY 2008 includes: $125,000 for SC-HQ Advisory Committee members travel; $441,000 for full-year travel funding for new SC-HQ Program Managers and support staff hired in late FY 2008 and FY 2009; $508,000 to specifically address SC-HQ program office travel funding concerns identified by recent COV reports; $5,000 for HFIR requirements; $10,000 for Isotope Program requirements; $239,000 for increased travel requirements by technical and administrative staff supporting acquisitions, finance, ES&H, the Integrated Assessment Schedule, and realignment from Other Services for rental/lease of passenger-carrying vehicles; and $91,000 for escalation.	+1,419
Support Services	
The increase supports update of mission specific HQ applications and cyber security protections required for HQ applications operations, and the management of SC-wide program level policies, issues and coordination across all SC sites to ensure appropriate alignment with Departmental direction ($1,811,000); training requirements for current staff, HFIR and Isotope Program requirements ($11,000); increased support services requirements for safety analysis and administrative support including HFIR and the Isotope Program ($492,000); increased energy research analysis and studies relevant to DOE's energy and science missions ($1,000,000); realignment of support services requirements for S&S and Emergency Operations Center from Other Services ($1,217,000); and 2.3% escalation ($465,000) for non-pay activities. Offsetting the increases is a decrease of $795,000 as a result of the transfer of funding responsibility for the PPC contractor support at the ORFSC to the Department's WCF where it will be shared by all of the Department's programs.	+ 4,201

	FY 2009 vs. FY 2008 ($000)
Other Related Expenses	
The increase supports requirements such as office space, utilities, communications, equipment, supplies, furniture and other related expenses associated with an increased SC workforce and maintaining current level of operations ($2,825,000); increased WCF requirements including STARS and STRIPES maintenance and operation; OMB A-123 reporting requirements support; contract support for building maintenance, supplies and property, transportation, travel, copy management and printing, Forrestal-Germantown shuttle bus, Forrestal safe haven project, and the On-Line Learning Center ($1,407,000); the allocable share of the Argonne National Laboratory charges for space, utilities, communications and other related expenses for the CH Office ($931,000) which includes realignment of Operation and Maintenance of Equipment to Operation and Maintenance of Facilities (i.e., building maintenance, janitorial, technical support—radios/alarms, and space modifications); HFIR requirements $90,000; and 2.3% escalation ($484,000) for non-pay activities. Offsetting the increases is a decrease for realignment of support services requirements for S&S and Emergency Operations Center to Support Services ($1,217,000).	+ 4,520
Total Funding Change, Science Program Direction	**+26,134**

Support Services by Category

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Technical Support			
Development of Specifications	300	300	258
System Definition	250	200	192
System Review and Reliability Analyses	540	500	510
Total, Technical Support	1,090	1,000	960
Management Support			
Directives Management Studies	—	338	—
Automated Data Processing	11,381	8,141	9,366
Training and Education	759	1,167	1,342
Reports and Analyses Management and General Administrative Services	10,524	9,570	12,749
Total, Management Support	22,664	19,216	23,457
Total, Support Services	23,754	20,216	24,417

Other Related Expenses by Category

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Other Related Expenses			
Rent to GSA	649	946	843
Rent to Others	118	616	1,268
Communications, Utilities, Miscellaneous	2,147	2,297	2,921
Printing and Reproduction	133	27	18
Other Services	4,916	5,469	5,867
Operation and Maintenance of Equipment	1,734	1,824	1,328
Operation and Maintenance of Facilities	1,877	—	2,013
Supplies and Materials	998	850	903
Equipment	606	2,269	1,722
Working Capital Fund	6,309	6,740	8,675
Total, Other Related Expenses	19,487	21,038	25,558

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Capital Equipment	126	—	447

Workforce Development for Teachers and Scientists

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Workforce Development for Teachers and Scientists					
Student Programs	4,274	4,433	-40[a]	4,393	4,615
Educator Programs	3,308	3,180	-29[a]	3,151	7,498
Program Administration and Evaluation	370	505	-5[a]	500	1,470
Total, Workforce Development for Teachers and Scientists	7,952	8,118	-74[a]	8,044	13,583

Public Law Authorizations:
Public Law 95–91, "Department of Energy Organization Act", 1977
The Albert Einstein Distinguished Educator Fellowship Act of 1994
The Omnibus Energy Legislation: Sec. 995. Educational Programs in Science and Mathematics amends Public Law 101–510, "DOE Science Education Enhancement Act", 1995
Public Law 109–58, "Energy Policy Act of 2005"
Public Law 110–69, "America COMPETES Act of 2007"

Mission

The Workforce Development for Teachers and Scientists (WDTS) program helps ensure that DOE and the Nation have a sustained pipeline of highly trained STEM workers. That workforce includes DOE federal employees, the DOE national laboratories, and more broadly, the university and private sector institutions that perform the science and technology required for DOE to achieve its goals in energy, environment, national security, and basis discovery. WDTS accomplishes this mission primarily by providing hands-on science and technology learning experiences to the Nation's students and educators of STEM. The Office of Science sponsors research at all of the Department's 17 national laboratories and the WDTS program, primarily through that laboratory system, offers students and educators an unparalleled opportunity to improve their understanding of science and to develop their ability to reason scientifically through direct experience.

Description

In 2007, a series of stakeholder meetings was held to assist in the development of a new direction that is consistent with the Administration's American Competitiveness Initiative (ACI), and the goals of the Congressionally-mandated Academic Competitiveness Council (ACC) Report, the 2005 Energy Policy Act, and the 2007 America Competes Act. As a result of this effort, the WDTS program has been restructured to include:

[a] Reflects a reduction for the 0.91% rescission in P.L. 110-161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.

- Rigorous evaluation of all WDTS programs, consistent with the recommendations of the ACC Report.
- Focused efforts for on-going programs for undergraduate students and educators that will fill critical skill gaps identified through a workforce assessment effort.
- Expansion of the Academies Creating Teacher Scientists (ACTS) program to 600 educators per year by FY 2010 and promotion of ACTS as a model Federal national program for K–12 educators.
- Implementation of several new initiatives in the outyears consistent with recommendations from WDTS stakeholders and the ACI.

WDTS programs are designed to provide students with an uninterrupted pathway to STEM careers at the Department, its national laboratories, and other institutions that support scientific disciplines consistent with the Office of Science's mission. WDTS supports the following subprograms that are designed to provide appropriate opportunities at various stages in STEM career paths:

Student Programs provide experiential learning opportunities to enhance student understanding of science and to increase their interest in pursuing science, technology, engineering, and math careers. Included within this newly restructured subprogram in FY 2009 are Science Undergraduate Laboratory Internship (SULI), Community College Institute (CCI), Pre-Service Teachers (PST) (formerly funded under the Undergraduate Research Internship subprogram), and the National Science Bowl (formerly funded under the Pre-College Activities subprogram).

Educator Programs make the world-class intellectual and physical assets of the Department available to the U.S. education community. Included within this newly restructured subprogram in FY 2009 are DOE Academies Creating Teacher Scientists (ACTS), Faculty and Student Teams (FaST), and the Albert Einstein Distinguished Educator Fellowship (formerly funded under the Graduate/Faculty Fellowships subprogram).

Program Administration and Evaluation activities, which include partnering with Federal agencies, industry, academic institutions, and professional associations to leverage resources and expertise in workforce development; developing and deploying rigorous evaluation methods for all programs; developing longitudinal workforce studies that track students and educators who participate in DOE programs; and improving outreach efforts to communicate to the broader public the role the Department plays in STEM education and the opportunities that are available to students and educators. Included within this newly restructured subprogram is ongoing support for the Laboratory Equipment Donation Program (formerly funded under the Graduate/Faculty Fellowship subprogram), Evaluation Studies, Workforce Studies, Technology Development and On-Line Application Systems, and Outreach (formerly supported within overall WDTS funding).

Significant Program Shifts

WDTS has established a rigorous program evaluation effort and a longitudinal workforce assessment study. This builds on recommendations from the Academic Competitiveness Council (ACC) Report and will enable WDTS to make effective investments in student and educator programs.

Student Programs

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Student Programs			
Science Undergraduate Laboratory Internship	2,437	2,549	2,600
Community College Institute of Science and Technology	279	319	350
Pre-Service Teachers	221	194	250
National Science Bowl®	1,337	1,331	1,415
Total, Student Programs	4,274	4,393	4,615

Description

The goal of the Student Programs subprogram is to continue the Department's long-standing role of providing mentor-intensive research experiences at the national laboratories for 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. By providing a wide variety of students with 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. Through the National Science Bowl and other student science and engineering competitions, DOE's laboratories and facilities provide experiences to inspire secondary students to continue and focus on STEM education and careers.

FY 2007 Accomplishments

- In 2006, more than 97% of all students in undergraduate research internships submitted abstracts (about 517) and research papers, which were published in the seventh edition of the "Journal of Undergraduate Research." The 21 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 San Francisco, California in February 2007.
- In the summer of 2007, 60 community college students, including 12 National Science Foundation funded participants, attended a 10-week mentor-intensive scientific research experience at several DOE national laboratories. Thirty-seven percent of the participating students came from under-represented groups in STEM disciplines and many were "non-traditional" students. Grades of abstracts for these students were statistically equal to those from the SULI program.
- FY 2007 marked the 17th anniversary of the DOE's National Science Bowl®. More than 12,000 high school students were hosted in the 64 regional science bowl events. Saturday science seminars at the National Science Bowl® weekend continued, introducing students to many contemporary issues and findings in contemporary scientific research. In FY 2007, two of the speakers were former National Science Bowl® participants. One of them is currently doing a post-doctoral fellowship at Brown University in theoretical physics. In FY 2007, 30 of the 64 high school 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. Fourteen of these teams raced in the stock category and the other 16 in the hill climb. Awards were presented to the top teams in this event.

The Middle School Science Bowl (MSSB), initiated in FY 2002 with 8 teams, expanded to 30 regional events with 30 teams traveling to the nationals in FY 2007. The national event was hosted by the National Renewable Energy Laboratory at the University of Denver. During FY 2007, 20 teacher workshops at regional MSSB sites were held to explain and demonstrate the design and construction of fuel cell model cars. The Middle School Science Bowl, initiated in FY 2002 with 8 teams, expanded to 30 regional events with 30 teams traveling to the nationals in FY 2007. The national event was hosted by the National Renewable Energy Laboratory at the University of Denver in Denver, Colorado.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Science Undergraduate Laboratory Internship	**2,437**	**2,549**	**2,600**

Science Undergraduate Laboratory Internship (SULI) supports a diverse group of students at DOE's national laboratories in individually mentored research experiences. Through these unique and highly focused experiences, students become a part of the national laboratory community and a source of talent to help the DOE meet its science mission goals. Students in the program: 1) apply on a competitive basis and are matched with mentors working in the student's fields of interest; 2) spend an intensive 10–16 weeks working under the individual mentorship of resident scientists; 3) produce a peer-reviewed abstract and research paper; and 4) attend seminars that broaden their view of science careers and help them understand how to become members of the scientific community. Goals and outcomes are measured based on students' research papers and abstracts, surveys, and an annual evaluation by a group of peers, both within and outside of the DOE. An undergraduate student journal is produced annually that publishes selected full length peer-reviewed research papers and all abstracts of SULI students. Full research papers published in the journal are presented by the student authors at the poster competition at the annual meeting of the American Association for the Advancement of Science (AAAS). The abstracts of the research conducted by these students' and their mentors' are posted on the AAAS web site. The National Science Foundation (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 at the national laboratories, academia, and industry. A system is being refined to track students during their academic and career paths.

In FY 2007, with DOE, NSF, and other leveraged support, 16 students participated in the fall semester program, 26 students participated in the spring semester program, and 370 students participated in the summer with 22 from NSF programs. The DOE contribution will support an estimated 360 students in FY 2008 and 365 in FY 2009.

Community College Institute of Science and Technology	**279**	**319**	**350**

Community College Institute (CCI) of Science and Technology is designed to address workforce shortages, particularly at the technician and semi-professional levels, and will help develop the workforce needed to continue building the DOE's capacity in critical areas for the next century. Because community colleges account for over 40% of the entire Nation's undergraduate enrollment and a

	(dollars in thousands)	
FY 2007	FY 2008	FY 2009

majority of under-represented minorities in STEM, this is an untapped and clear avenue to increase the number of U.S. scientists and engineers. The CCI targets students from under-represented populations in science and technology fields to increase the diversity of the workforce and provides a 10-week mentored research internship at a DOE national laboratory for highly motivated community college students. Students in the program: 1) apply online and are matched with mentors working in the student's field of interest; 2) spend an intensive 10 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 professional skills. Goals and outcomes are measured based on a students' research papers and abstracts, surveys, and external evaluation. An ongoing undergraduate student journal was created to publish selected full research papers and all abstracts of students in this activity. Through a Memorandum of Understanding with the NSF starting 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 CCI.

In FY 2007, 48 DOE supported students directly participated in this internship. Twelve additional students were part of one of the NSF programs that provided funding for them to participate in CCI. An estimated 52 students will participate in FY 2008 and 55 students will participate in FY 2009.

Pre-Service Teachers	**221**	**194**	**250**

The Pre-Service Teachers (PST) activity is for students who are preparing for a teaching career in a STEM discipline. This effort addresses the national need to improve the content knowledge of STEM teachers prior to entering the teaching workforce. The NSF entered into a collaboration with DOE on this activity in FY 2001. This allows NSF's undergraduate pre-service programs to include a PST internship in the opportunities they provide to students. Students in this program: 1) apply on a competitive basis and are matched with mentors working in the student's field of interest; 2) spend an intensive 10 weeks working under the mentorship of a master teacher and laboratory scientist to help maximize the building of content knowledge and skills through the research experience; 3) produce an abstract and an educational module related to their research and an optional research paper, poster, or oral presentation; and 4) attend professional enrichment activities, workshops, and seminars that help students apply what they learn to their academic program and the classroom, help them understand how to become members of the scientific community, and improve their communication and other professional skills. Goals and outcomes are measured based on students' abstracts, education modules, surveys, and external evaluation. In FY 2007, PST was hosted at six DOE national laboratories with 29 participating students. Seven of these students were from NSF programs that provide funding for their participation in this program at a DOE laboratory. In FY 2008, funding will support about 26 students at four national laboratories. In 2009, the increase will support about 35 students at six national laboratories.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
National Science Bowl®	**1,337**	**1,331**	**1,415**

The National Science Bowl® (NSB) is a nationally recognized, prestigious academic event for high school and middle school students. It has attained its level of recognition and participation through a grass-roots design, which encourages the voluntary participation of professional scientists, engineers, and educators from across the Nation. Students answer questions on topics in astronomy, biology, chemistry, mathematics, and physics in a highly competitive, Jeopardy-style format. Since 1991, more than 150,000 students have participated in regional and national competitions.

Since 1991, the NSB's high school competition has encouraged high school students from across the Nation to excel in mathematics and science and to pursue careers in those fields. The National Science Bowl® provides students and teachers with a forum to receive recognition for their talent and hard work by solving traditional academic problems in selected fields of science and math, in addition to their activity in various hands-on science challenges. The high school teams that win their regional events attend the four-day national finals held in Washington, DC. During this time, the students participate in a day of scientific seminars and science discovery activities with the students "doing" science, with the event culminating in an academic competition.

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 become involved with bright, enthusiastic high and middle school students. WDTS funding provides all of the travel and lodging expenses for each winning team, seminar speakers, trophies, awards, and items and equipment for the various hands-on and interactive science activities and events.

It is well established in educational evaluation literature that the middle school years are perhaps the most important time to attract and retain student interest in science and math. The middle school National Science Bowl® was designed to take advantage of this fact by bringing DOE science to middle school students and teachers in a way that will engage their interest and potentially lead to careers in science and technology.

The NSB's middle school science bowl has two events: an academic competition in mathematics and science; and a competition 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 to help them understand the future energy challenges that our Nation is facing. Students who win regional events enjoy a trip to a national laboratory and participate in the three-day national finals at the University of Denver.

The number of regional events remains relatively constant from one year to the next with 66 to 68 high school and 29 to 39 middle school teams participating in recent years. In FY 2009, support for the National Science Bowl® is increased to reflect cost increases in travel, lodging, and associated activities and speakers.

Total, Student Programs	**4,274**	**4,393**	**4,615**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Science Undergraduate Laboratory Internship	
The number of students participating in this program will increase by 5 in FY 2009, from 360 in FY 2008 to a total of 365 in FY 2009.	+51
Community College Institute of Science and Technology	
The number of students participating in this program will increase by 3 in FY 2009, from 52 in FY 2008 to a total of 55 in FY 2009.	+31
Pre-Service Teachers	
The number of student participating in this program will increase by 9 in FY 2009, from 26 in FY 2008 to a total of 35 in FY 2009.	+56
National Science Bowl®	
Support is increased to reflect cost increases in travel, lodging, and associated activities and speakers.	+84
Total Funding Change, Student Programs	**+222**

Educator Programs

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Educator Programs			
DOE Academies Creating Teacher Scientists	2,320	2,184	6,398
Faculty and Student Teams	243	250	300
Albert Einstein Distinguished Educator Fellowship	745	717	800
Total, Educator Programs	3,308	3,151	7,498

Description

DOE Academies Creating Teacher Scientists (DOE ACTS) program establishes the basic framework for DOE's long-term relationships with K–12 educators. Through DOE ACTS, educators improve their content knowledge in areas of high importance to DOE missions and become contributing researchers in the scientific community. As highly trained leaders in STEM education, they are a key element of the effort to reform our Nation's science education and help to meet the President's goal of a qualified educator in every classroom.

The Faculty and Student Teams (FaST) program will benefit the individual faculty, their students, and their respective institutions by giving them the training needed to successfully compete for Federal science research grants.

The Albert Einstein Distinguished Educator Fellowship benefits Federal agencies and Congressional offices because these outstanding educators provide their "real world" classroom expertise and advice to national policy makers. After their Fellowship, the educators return to their school districts better prepared to be leaders at the local, regional, and national levels, and bring knowledge of Federal programs that provide resources to their school districts.

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 strongly suggests that educators hold the key to increasing the number and quality of the science, technology, and engineering workforce.

WDTS's Educator Programs are designed to build a strong cadre of highly qualified STEM educators. The President's "No Child Left Behind" initiative has placed great emphasis on providing a "qualified teacher in every classroom," but educators highly trained in modern science and math are in short supply in the Nation's classrooms. In 1999, for example, only 41% of U.S. eighth graders received instruction from a math educator 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).

The business community is also sounding the alarm about the future of the workforce and our Nation's ability to maintain technological superiority and is calling for education reform targeted at educators. 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."

DOE's unique role in educator training derives from the existence of its national laboratories. The primary goal of DOE ACTS is to create a cadre of STEM educators 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 designed around 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."

FY 2007 Accomplishments

- In 2007, six national laboratories—Argonne, Brookhaven, Fermi National Accelerator Laboratory, Lawrence Berkeley, Oak Ridge, and Pacific Northwest—placed 42 Faculty and Student Teams, with 27 of those being partially supported by NSF. For summer 2007, there were a total of 61 NSF funded students and 27 faculty that participated on FaST teams. These participants were eligible for supplemental funding from NSF to pay for their stipends and travel. Since the program began, more than 30 FaST faculty have submitted 80 grant proposals to federal institutions/agencies.
- By leveraging resources and collaborating with other service agencies, the Albert Einstein Distinguished Educator Fellowship activity for FY 2007–2008 placed 17 outstanding K–12 science, math, and technology educators: 4 in Congressional offices, 3 at DOE, 1 at the National Aeronautics and Space Administration (NASA), 8 at NSF, and 1 at the National Oceanic and Atmospheric Administration (NOAA).

Detailed Justification

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
DOE Academies Creating Teacher Scientists	**2,320**	**2,184**	**6,398**

DOE ACTS requires a three-year commitment by educators to participate in this program, which is based on research in teacher professional development that indicates that change takes place over an extended period of time and that multi-year professional development is required to make the necessary differences. Each educator spends an intensive four to eight weeks annually at DOE national laboratories working under the mentorship of master educators and laboratory scientists to build content knowledge, research skills, and a lasting connection with the scientific community through the research experience. Master educators, who are expert K–12 educators and adept in both scientific research and scientific writing, act as liaisons between the mentor scientists and the educator participants. This helps the educators transfer the research experiences to their classrooms. Follow-on support is considered critical. Master educators and other teacher participants receive an $800 per week stipend plus travel and housing expenses.

The National Commission on Mathematics and Science Teaching indicates that professional staff development is one of the most effective ways of improving the achievement of K–12 students. The National Academy of Sciences (NAS) and Teachers Advancement Program (TAP) reports point to educators 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 educators through direct

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009

retraining. However, the laboratories can play a pivotal role in reforming the Nation's STEM education by creating sufficient numbers of highly trained education leaders as agents of change in STEM education. This is accomplished by providing carefully designed mentor-intensive training for science and math educators that will allow them to more effectively teach; to attract their students' interests to science, mathematics, and technology careers; and to improve student achievement. Educators apply on a competitive basis and are matched with mentors working in their subject fields of instruction.

All educators 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, long-term support is provided in following years through communication with other educators and laboratory scientists 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 educator participant, successful development of a professional development plan by each educator, attainment of a leadership role, and impact on local STEM education and student achievement. External evaluation of program effectiveness will include visits to participant educators' schools to assess the long-term impact of the program on student achievement. External evaluators submitted a report on the first program year, which found that the success of this program relies on proper placement of each participant to match their professional developmental needs and the follow-on interaction between the educators and the national laboratories

The DOE ACTS, which began in FY 2004, funded 145 teachers in FY 2007 and will fund 114 teachers in FY 2008. As a result of the FY 2008 Energy and Water Development and Related Agencies Appropriations Act, no new teachers are added in FY 2008. The FY 2009 request would fund a total of 341 teachers and will increase the stipends for all teachers.

Faculty and Student Teams	**243**	**250**	**300**

The Faculty and Student Teams (FaST) summer internship/fellowship provides an opportunity for faculty from colleges and universities with limited prior research capabilities and those institutions serving women or minorities to participate with up to three of their undergraduate students in a mentor-intensive science research project at one of six DOE national laboratories. Faculty members may come back to the laboratory in subsequent summer terms. The undergraduate students on the FaST teams are funded either by the Science Undergraduate Laboratory Internship (SULI) or Community College Institute of Science and Technology (CCI) activities. Over a 10-week summer visit to the laboratory, the faculty member is introduced to new and advanced scientific techniques that contribute to their professional development and help them prepare their students for careers in science, engineering, computer sciences, and technology. FaST activities at SC laboratories are being conducted in collaboration with the NSF. Faculty members from minority serving institutions have overwhelmingly identified the FaST program as providing a high quality developmental scientific experience. Faculty from minority serving institutions and other populations under-represented in the fields of science, engineering, and technology are encouraged to take advantage of the FaST opportunity to prepare students for careers in science, engineering, computer sciences, and technology and for their own professional development. In part, because of increasing support from the NSF through an existing partnership created in 2001, the number of teams has increased from 6 in FY 2002 to 42 teams in FY 2007. With similar support from NSF, there will be 9 teams in FY 2008 and 11 teams in FY 2009.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Albert Einstein Distinguished Educator Fellowship	**745**	**717**	**800**

The Albert Einstein Distinguished Educator Fellowship Awards for outstanding K–12 science, mathematics, and technology educators brings real classroom and education expertise to Congress and to DOE's and other Federal agencies' education and outreach activities. These outstanding educators provide practical insights and "real world" perspectives to policy makers and program managers. The Einstein Fellowship is a valuable professional growth opportunity for the educators because they return to their education field with knowledge of Federal resources and an understanding of national education policies. In FY 2007, with the organizational support of DOE, other Federal agencies (including the National Science Foundation, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, and the National Institutes of Health) were able to place 17 teachers as Einstein Fellows. Of these, five were directly supported by WDTS and two were supported by Office of Science research programs (four fellows in Congress and three at DOE). The FY 2009 request will directly support four fellows in Congress and two at DOE, an increase of one fellow (five in FY 2008). The increased funding will also augment stipends and health insurance for the participants, and allow for the continued organizational support for the placement of additional fellows at other Federal agencies.

	FY 2007	FY 2008	FY 2009
Total, Educator Programs	**3,308**	**3,151**	**7,498**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
DOE Academies Creating Teacher Scientists	
The number of educators participating in DOE ACTS will increase by 227 in FY 2009, from 114 in FY 2008 to a total of 341 in FY 2009, and stipends for all teachers will be increased to be competitive with other scientific internship programs.	+4,214
Faculty and Student Teams	
The number of teams supported by DOE will increase by 2 in FY 2009, from 9 in FY 2008 to 11 in FY 2009.	+50
Albert Einstein Distinguished Educator Fellowship	
There will be 1 additional participant supported by WDTS in FY 2009, an increase from 5 in FY 2008 to 6 in FY 2009. In addition, stipends and other living expense increases will be supported.	+83
Total Funding Change, Educator Programs	**+4,347**

Program Administration and Evaluation

Funding Schedule by Activity

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Program Administration and Evaluation			
Evaluation Studies	50	150	600
Workforce Studies	50	—	500
Laboratory Equipment Donation Program	90	75	90
Technology Development & Online Application	130	175	180
Outreach	50	100	100
Total, Program Administration and Evaluation	370	500	1,470

Description

The Program Administration and Evaluation (PA&E) subprogram is designed to provide the resources required for effective WDTS program management and delivery. Those resources take two forms: analytical/evaluation studies that will be used by WDTS program managers to make efficient use of resources that are informed by results and lessons learned; and, non-financial resources that enable WDTS performers and participants to more effectively participate in WDTS programs.

Evaluation Studies and Workforce Studies provide the analytical resources required by WDTS to make informed judgments about the effectiveness and benefits of WDTS program investments. Evaluation studies have been developed in a manner consistent with the recommendations of the Academic Competitiveness Council (ACC) and a number of rigorous studies that focus on individual performance, program effectiveness, and the overall accomplishment of WDTS goals. An initial review of WDTS evaluation efforts by an Office of Science and Technology Policy (OSTP) working group found that they are rigorous and consistent with ACC requirements. Workforce Studies focus on the critical skill gaps, by scientific discipline, which may exist within the DOE/SC Federal and national laboratory workforces. Both the Evaluation Studies and Workforce Studies are designed to be long-term, sustained efforts that will provide a baseline of data and results that can be used to effectively manage WDTS programs.

The other activities contained within the PA&E subprogram enable WDTS performers to more effectively participate in WDTS programs. The Laboratory Equipment Donation program is being expanded to include middle schools and high schools (currently only universities may participate) so that educators who participate in the DOE ACTS program may take advantage of DOE’s equipment donation efforts. The Technology Development and Online Application activity provides the online resources required by students and educators to apply for resources, conduct general outreach, and manage evaluation studies (for example, the educator electronic portfolio). The Outreach activity is designed to reach under-represented populations and to form “trusted partnerships” with associations, industry and other groups to leverage WDTS investments. Future planned activities include the DOE Mentor Awards activity which will solidify DOE’s longstanding capacity to recruit, train and effectively utilize the large cadre of mentor scientists who provide the foundation for WDTS’ student and educator programs. This program will develop consistent standards and training for DOE mentors and provide incentives for mentors to participate in all of the WDTS programs.

WDTS, through focus groups with key stakeholders and interactions with other Federal agencies, Congress, and OMB, determined in FY 2007 that two major gaps existed in its program portfolio: rigorous evaluation and workforce assessments of existing programs that could guide investment decisions; and, effective outreach efforts and support activities to enable program participants to be more successful in WDTS programs.

The Academic Competitiveness Council (ACC), in a 2007 report, found that most Federal agencies, including the Department of Energy, were not conducting rigorous evaluations of their science education and workforce development programs. This absence of rigorous evaluation called into question the effectiveness and benefits of those programs because of a lack of externally-validated data and analysis. WDTS has conducted a full review of the academic literature and best practices for rigorous evaluation of experiential learning programs and has developed a comprehensive evaluation and workforce assessment program that fills the gap identified by the ACC.

WDTS stakeholders participated in a strategic planning process that resulted in a redesign of WDTS programs and the publication of the WDTS Future Workforce Strategy in July 2007. This intensive effort, which included participation by more than 100 stakeholder groups, has led to greater leveraging and partnering of WDTS programs. In addition, WDTS stakeholders have clearly articulated the need for improved outreach, particularly to under-represented populations and institutions. WDTS programs currently have strong participation by minorities and women, but not to the degree that the changing demographics of the Nation suggest will be needed in coming decades. Improvements to outreach and to on-line resources were identified as a key to the success of WDTS programs. The preliminary design of the WDTS workforce assessment was completed in FY 2007 and full implementation will begin in FY 2008.

Another key resource that should be strengthened is the population of DOE mentor scientists who form the foundation for all of the WDTS programs. Currently, mentors are recruited and trained by DOE laboratories with very little assistance from WDTS. This limits the number and utility of those mentor scientists because they are not managed as a national resource.

2007 Accomplishments

- A Committee of Visitors (COV) reviewed WDTS program management and evaluation efforts in September 2007 in a first-ever external peer review of WDTS programs. They found that WDTS priorities were aligned with DOE and administration priorities but recommended stronger outreach to underrepresented populations and greater linkages to SC R&D programs. Program managers used the results of the COV process to adjust programs and improve program efficiency/effectiveness by reallocating resources to high priority programs and focusing evaluation efforts on national objectives.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Evaluation Studies	**50**	**150**	**600**

WDTS will implement a rigorous, comprehensive, and sustained evaluation of all Office of Science experiential education programs consistent with the requirements specified by the Academic Competitiveness Council. Funding in FY 2007 was provided for the development of an evaluation plan

	FY 2007	FY 2008	FY 2009

(dollars in thousands)

and pilot evaluations. Full implementation begins in FY 2008 at $150,000 and increases to $600,000 in FY 2009 to provide in-depth and systemic evaluation of all WDTS programs.

Workforce Studies	**50**	**—**	**500**

Workforce Studies focus on the critical skill gaps, by scientific discipline, which may exist within the DOE/SC Federal and national laboratory workforces. These studies are designed to be long-term, sustained efforts that will provide a baseline of data and results that can be used to effectively manage WDTS programs. Funding in FY 2007 was provided for the development of a workforce study plan. No funding is provided in FY 2008 as a result of the FY 2008 Energy and Water Development and Related Agencies Appropriations Act. Therefore, full implementation begins in FY 2009 to provide in-depth and systemic review of workforce requirements.

Laboratory Equipment Donation Program	**90**	**75**	**90**

The Laboratory Equipment Donation Program (formerly the Energy Related Laboratory Equipment [ERLE] program) provides excess equipment to faculty at institutions of higher education for energy-related research. Through the Energy Asset Disposal System, DOE sites identify laboratory equipment that is then listed on the ERLE website, which is maintained by the Office of Scientific and Technical Information and updated several times a week. Colleges and universities can search for equipment of interest to them and apply via the website. DOE property managers approve or disapprove the applications. The equipment is free; the receiving institution pays for shipping costs. In FY 2007, more than 900 individual pieces of equipment with an original value of more than $17,000,000 were donated. WDTS intends to expand this program in FY 2009 to middle schools and high schools.

Technology Development & On-Line Application	**130**	**175**	**180**

Technology Development and Online-Application Systems provides for the enhancement and maintenance of the WDTS application and electronic portfolio system. The increase in FY 2008 will support the design of a single portal for all of the DOE STEM education programs, which will continue to be implemented in FY 2009.

Outreach	**50**	**100**	**100**

Outreach has four components: providing information to WDTS program alumni (science bowls, undergraduate research internships, educator programs, etc.) to encourage their continued participation in DOE programs; creating a common database of internship opportunities, fellowships, and other research-based educational opportunities at DOE; assisting in the coordination of outreach activities with other Federal agencies; and enhancing communication about WDTS programs to the public. Funding in FY 2007 and prior years provided development of an outreach plan. Beginning in FY 2008, this plan will be implemented.

Total, Program Administration and Evaluation	**370**	**500**	**1,470**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Evaluation Studies	
Full implementation of the WDTS evaluation program is supported in FY 2009 to provide in-depth and systemic review of all WDTS programs.	+450
Workforce Studies	
WDTS requires the data and analysis from these studies to effectively manage its programs and to identify critical skill shortages in the SC and DOE national laboratory workforces. FY 2009 funding will provide for full implementation of this study across the DOE complex and analysis of data.	+500
Laboratory Equipment Donation Program	
The increase will support expansion of this program to middle and high schools in FY 2009.	+15
Technology Development & On-Line Application	
Improvements to the WDTS on-line process was identified as a key need by WDTS stakeholders. Funding supports continued design and implementation of a single portal for all of the DOE STEM education programs.	+5
Total Funding Change, Program Administration and Evaluation	**+970**

SC Education Crosscut

The Office of Science (SC) research programs**—**Basic Energy Sciences, Advanced Scientific Computing Research, Biological and Environmental Research, High Energy Physics, Nuclear Physics, and Fusion Energy Sciences**—**support development of the R&D workforce through support of undergraduate researchers, graduate students working toward doctoral degrees, and postdoctoral associates developing their research and management skills. The R&D workforce developed under these programs, as well as within the Workforce Development for Teachers and Scientists program, provide new scientific talent in areas of fundamental research and also provide talent for a wide variety of technical and industrial areas that require the problem solving abilities, computing skills, and technical skills developed through education and experience in fundamental research. In addition, the SC 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 SC-supported facilities each year. The work that these young investigators perform at SC facilities is supported by a wide variety of sponsors including SC and other Departmental research programs, other federal agencies, and private institutions.

Funding Summary

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Undergraduate Programs	**5,191**	**5,753**	**6,413**
▪ **Advanced Scientific Computing Research**—Awards to under-represented groups in Applied Mathematics, Computer Science, Networking R&D, and Computational Science.	**1,200**	**1,600**	**2,000**
▪ **Biological and Environmental Research**	**526**	**528**	**528**
• Summer Undergraduate Research Experience	426	428	428
• American Chemical Society Summer School in Nuclear and Radiochemistry	100	100	100
▪ **Fusion Energy Sciences**	**268**	**395**	**395**
• National Undergraduate Fellowship Program	248	370	370
• Plasma Physics Speakers Bureau	20	25	25
▪ **High Energy Physics**—Minority Outreach Program, Argonne National Laboratory	**20**	**20**	**20**
▪ **Nuclear Physics**	**150**	**180**	**180**
• American Chemical Society's Nuclear Chemistry Summer School	50	65	80
• Minority participation in physics research, Argonne National Laboratory	100	100	100

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
• Conference for Undergraduate Women in Physics at Yale University	—	15	—
▪ **Workforce Development for Teachers and Scientists**	**3,027**	**3,030**	**3,290**
• Science Undergraduate Laboratory Internship	2,437	2,415	2,600
• Community College Institute of Science and Technology	279	311	350
• Pre-Service Teachers	221	214	250
• Laboratory Equipment Donation Program	90	90	90
Graduate Programs	**16,379**	**18,138**	**19,121**
▪ **Advanced Scientific Computing Research**	**13,395**	**14,298**	**15,298**
• Computer Science Graduate Fellowships	4,000	5,000	6,000
• Scientific Discovery through Advanced Computing Institutes.(includes Undergraduates)	8,100	8,100	8,100
• Stanford Synchrotron Radiation Laboratory Student Training	300	200	200
• Graduate Research Environmental Fellowships	995	998	998
▪ **Biological and Environmental Research**	**633**	**539**	**503**
• American Meteorological Society /Industry/Government Graduate Fellowship	23	24	24
• Life Sciences and Medical Sciences—Minority Colleges and Universities Support	102	102	102
• 2007 NASA Space Radiation Summer School support	50	—	—
• Annual meeting of Nobel Laureates and Young Scientists in Lindau, Germany	50	100	100
• Marine Biological Laboratory Summer Course at Woods Hole, Massachusetts	15	15	15
• Gordon Research Conferences	38	10	—
• International Society for Computational Biology annual workshop in “intelligent systems for molecular biology,” (student travel and registration)	35	35	—
• Summer of Applied Geophysical Experience	30	30	30

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
• Post-Doctoral Atmospheric Research Measurement (ARM) Science program: European Centre for Medium-range Weather Forecasts	117	112	127
• Post-Doctoral ARM Science program—Geophysical Fluid Dynamics Laboratory	85	88	92
• Workshop, Mentoring Physical Oceanography Women to Increase Retention	75	—	—
• Gordon Conference on Atmospheric Radiation	13	13	13
• Fourteenth-Sixteenth Microbial Genomics Conference 2006–2008.	—	10	—
▪ **Basic Energy Sciences**	**570**	**914**	**860**
• Mineralogical Society and Geochemical Society Short Courses	10	25	25
• Pan American Advanced Studies Institutes Program Solicitation NSF 01–48	200	200	200
• American Physical Society Workshop on Energy Research for Physics Graduate Students and Postdoctoral Associates	—	29	—
• Nobel Laureates and Young Scientists in Lindau, Germany	25	25	—
• Argonne National Laboratory National School on Neutron and X-ray Scattering	150	150	150
• Los Alamos National Laboratory Neutron School	35	35	35
• Oak Ridge National Laboratory Spallation Neutron Source Instrumentation Fellowship	150	450	450
▪ **Fusion Energy Sciences**	**746**	**1,352**	**1,350**
• Graduate Fellowship Program	436	882	880
• Postdoctoral Research Program	310	470	470
▪ **High Energy Physics**	**905**	**905**	**905**
• Particle Accelerator School	817	817	817
• Italian Student Exchange Program	88	88	88
▪ **Nuclear Physics**	**130**	**130**	**205**
• Hampton University's summer school	45	45	45
• Exotic Beam Physics summer school	15	15	15

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
• Quark Matter Series of International Conferences	—	—	75
• Institute for Nuclear Theory	70	70	70
Educator Programs, K–12 students	**6,696**	**6,719**	**13,172**
▪ **Biological and Environmental Research**	**661**	**650**	**642**
• ARM Southern Great Plains Site Scientist support for K–12 educational outreach at the University of Oklahoma	50	50	50
• ARM Education and Outreach K–12	400	400	400
• Science Literacy for Mid-career Public Radio Participants	206	200	192
• Applied & Environmental Microbiology Gordon Research Conference (July 2007).	5	—	—
▪ **Fusion Energy Sciences**	**640**	**837**	**850**
• Advancing Precollege Science and Mathematics Education	199	260	260
• Professional development for science, math, and technology for K–12 teachers in the Trenton, New Jersey	165	245	245
• Plasma Physics Summer Institute and Contemporary Physics Education Project	100	125	125
• Fusion/Plasma Education	124	155	155
• Wonders of Physics Traveling Show	52	52	65
▪ **High Energy Physics**—QuarkNet	**750**	**750**	**750**
▪ **Workforce Development for Teachers and Scientists**	**4,645**	**4,482**	**10,930**
• Science Bowl for Middle and High School Students	1,337	1,331	1,415
• DOE Academies Creating Teacher Scientists	2,320	2,184	8,415
• Faculty and Student Teams research experience	243	250	300
• Albert Einstein Distinguished Educator Fellowship	745	717	800
Total, SC Education Funding	**28,266**	**30,610**	**38,706**

Safeguards and Security

Funding Profile by Subprogram

(dollars in thousands)

	FY 2007 Current Appropriation	FY 2008 Original Appropriation	FY 2008 Adjustments	FY 2008 Current Appropriation	FY 2009 Request
Safeguards and Security					
Protective Forces	31,652	33,032	—	33,032	34,384
Security Systems	6,705	6,993	—	6,993	7,940
Information Security	4,169	3,781	—	3,781	4,028
Cyber Security	18,322	18,070	-646[a]	17,424	19,515
Personnel Security	5,552	5,153	—	5,153	5,615
Material Control and Accountability	2,355	2,401	—	2,401	2,348
Program Management	7,075	7,162	—	7,162	6,773
Subtotal, Safeguards and Security	75,830	76,592	-646[a]	75,946	80,603
Less Security Charge for Reimbursable Work	-5,605	-5,605	—	-5,605	—
Total, Safeguards and Security	70,225	70,987	-646[a]	70,341	80,603

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act", 1977
Public Law 109-58, "Energy Policy Act of 2005"
Public Law 110-69, "America COMPETES Act of 2007"

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 and destruction of Department of Energy (DOE) assets, and hostile acts that may cause adverse impacts on fundamental science, national security, the health and safety of DOE and contractor employees, the public, and the environment.

Protective Forces

The Protective Forces activity provides for security guards or security police officers and equipment, training and maintenance needed to effectively carry out the protection tasks during normal and increased or emergency security conditions (SECON). This request is adequate for up to 60 days of heightened security at the SECON 2 level.

Security Systems

The Security Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware include items such as, fences, barriers, lighting, sensors, and entry control devices.

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[a] Reflects a reduction for the 0.91% rescission in P.L. 110-161, the Energy and Water Development and Related Agencies Appropriations Act, 2008.

Information Security

The Information Security activity ensures that materials and documents that may contain classified or "Official Use Only" (OUO) information are accurately and consistently identified; properly reviewed for content; appropriately marked and protected from unauthorized disclosure; and ultimately destroyed in an appropriate manner.

Cyber Security

The Cyber Security activity ensures that classified and OUO information that is electronically processed or transmitted is properly identified and protected, and that all electronic systems have an appropriate level of infrastructure reliability and integrity. This involves perimeter protection, intrusion detection, firewall protection, and user authentication. Cyber security also includes enhancements in network traffic logging and monitoring, risk assessments, and improvements in incident response. It provides for the development of virtual private networks and increased security for remote login and wireless connections.

Personnel Security

The Personnel Security activity includes security clearance programs, employee security education, and visitor control. Ongoing implementation and investigative activity for the Personal Identity Verification (PIV) program is also supported under the Personnel Security activity. Employee education and awareness is accomplished through initial, refresher, and termination briefings, computer-based training, special workshops, publications, signs, and posters.

Material Control and Accountability

The Material Control and Accountability activity provides for the control and accountability of special nuclear materials, including training of personnel for assessing the amounts of material involved in packaged items, process systems, and wastes. Additionally, this activity provides the programmatic mechanism to preclude theft or operational loss of special nuclear material. 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

Beginning in FY 2009, all funding associated with safeguards and security charges at SC laboratories will be requested through direct appropriations. In FY 2008 and before, a portion of safeguards and security expenses was recovered through charges to reimbursable customers at the laboratories.

Detailed Justification

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Ames Laboratory	**946**	**944**	**974**
▪ Protective Forces	152	179	184
▪ Security Systems	40	17	36
▪ Information Security	2	—	—
▪ Cyber Security	674	674	675
▪ Personnel Security	33	33	35
▪ Material Control and Accountability	5	1	6
▪ Program Management	40	40	38

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation, and oversight in the areas of protective forces, security systems, cyber security, personnel security, material control and accountability, and program management. A protective force is maintained to provide protection of personnel, equipment, and property from acts of theft, vandalism, and sabotage through facility walk-through, monitoring of electronic alarm systems, and emergency communications.

	FY 2007	FY 2008	FY 2009
Argonne National Laboratory	**8,375**	**8,527**	**8,562**
▪ Protective Forces	3,000	3,000	3,000
▪ Security Systems	744	744	744
▪ Information Security	350	350	350
▪ Cyber Security	1,905	1,905	1,940
▪ Personnel Security	1,070	1,070	1,070
▪ Material Control and Accountability	754	830	830
▪ Program Management	552	628	628

The Argonne National Laboratory Safeguards and Security program provides protection of nuclear materials, classified matter, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, espionage, and other hostile acts that may cause risks to national security, the health and safety of DOE and contractor employees, the public, or the environment. Program activities include protective forces, security systems, information security, cyber security, personnel security, material control and accountability, and program management.

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
Brookhaven National Laboratory	**10,710**	**10,834**	**11,451**
▪ Protective Forces	5,392	5,510	6,030
▪ Security Systems	879	878	853
▪ Information Security	568	568	529
▪ Cyber Security	2,037	2,037	2,220
▪ Personnel Security	528	528	496
▪ Material Control and Accountability	491	498	548
▪ Program Management	815	815	775

The Brookhaven National Laboratory program provides physical protection of personnel and laboratory facilities. Information security provides for site-wide data integrity and training. The laboratory 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. An increase in protective forces provides for required training and equipment, including Level III ballistic vests. Increased funding in cyber security provides for certifications, security testing and evaluation, an enhanced intrusion detection system program, network access control, forensics, and upgrade spam filtering technology.

Chicago Office	**488**	**1,607**	**2,150**
▪ Protective Forces	8	1,600	1,600
▪ Cyber Security	480	—	—
▪ Personnel Security	—	7	550

The Chicago Office through a direct contract provides guard force services to monitor actions of visitors and mitigate threats to employees and facilities for the Fermi National Accelerator Laboratory. Also included is Homeland Security Presidential Directive-12 implementation cost and maintenance through procurement with the General Services Administration.

Fermi National Accelerator Laboratory	**2,908**	**1,686**	**1,742**
▪ Protective Forces	1,224	181	13
▪ Security Systems	538	464	560
▪ Cyber Security	965	965	977
▪ Material Control and Accountability	46	46	44
▪ Program Management	135	30	148

The Fermi National Accelerator Laboratory (Fermilab) Safeguards and Security program efforts are directed at maintaining operations to protect personnel and the facility. The cyber security element addresses the network segmentation requirements that were designed to enhance the protection mechanisms for sensitive unclassified information, such as personally identifiable information. Starting at the end of FY 2007, protective forces for Fermilab were provided through a direct contract administered and funded under the Chicago Office.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Lawrence Berkeley National Laboratory	**4,894**	**4,985**	**5,006**
▪ Protective Forces	1,668	1,868	1,782
▪ Security Systems	460	334	355
▪ Cyber Security	2,024	2,024	2,025
▪ Personnel Security	109	134	129
▪ Material Control and Accountability	24	14	20
▪ Program Management	609	611	695

The Lawrence Berkeley National Laboratory Safeguards and Security program provides physical protection of personnel and laboratory facilities. This is accomplished by integrating various security services including protective forces, security systems, cyber security, personnel security, material control and accountability of special nuclear material, and program management.

Oak Ridge Institute for Science and Education	**1,585**	**1,579**	**1,617**
▪ Protective Forces	314	274	253
▪ Security Systems	102	102	237
▪ Information Security	148	182	123
▪ Cyber Security	610	610	610
▪ Personnel Security	100	100	117
▪ Program Management	311	311	277

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection or 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. Since the inventory is static, it is accounted for under program management.

	FY 2007	FY 2008	FY 2009
	(dollars in thousands)		
Oak Ridge National Laboratory	**7,473**	**7,897**	**8,895**
▪ Security Systems	2,225	2,789	3,222
▪ Information Security	579	449	790
▪ Cyber Security	2,016	2,355	2,590
▪ Personnel Security	709	764	798
▪ Material Control and Accountability	408	385	326
▪ Program Management	1,536	1,155	1,169

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. Protective force resources for Oak Ridge National Laboratory (ORNL), including those to protect the national U233 Vault at Building 3019, are funded within the Oak Ridge Office. Additional funding provides for communication equipment and replacement of portions of aging security systems. Efforts in information security are enhanced in response to increased DOE emphasis in this area. Cyber security funding increases to implement authentication infrastructure, maintain accreditation and certification of cyber security master plans, and to upgrade and maintain the technical infrastructure.

Oak Ridge Office	**18,476**	**17,849**	**18,819**
▪ Protective Forces	16,312	16,838	17,921
▪ Security Systems	196	157	157
▪ Information Security	765	475	375
▪ Cyber Security	338	—	—
▪ Personnel Security	865	379	366

The Oak Ridge Office Safeguards and Security program provides for contractor protective forces for ORNL, including protection of a Category I special nuclear material facility, Building 3019 ($4,700,000). In addition, protective forces are provided for the Federal Office Building complex. Other smaller activities to support Oak Ridge National Laboratory’s mission include: security systems, information security, and personnel security.

Office of Scientific and Technical Information	**483**	**470**	**490**
▪ Protective Forces	15	15	15
▪ Security Systems	43	30	30
▪ Cyber Security	400	400	420
▪ Program Management	25	25	25

The Office of Scientific and Technical Information's mission is to collect, preserve, disseminate, and leverage the scientific and technical information resources of DOE to expand the knowledge base of science and technology and facilitate scientific discovery and application. Safeguards and Security program activities include protective forces, security systems, cyber security, and program management.

(dollars in thousands)

	FY 2007	FY 2008	FY 2009
Pacific Northwest National Laboratory	**11,318**	**11,143**	**11,163**
▪ Security Systems	1,356	1,356	1,462
▪ Information Security	1,757	1,757	1,861
▪ Cyber Security	2,904	2,260	2,700
▪ Personnel Security	2,138	2,138	2,054
▪ Material Control and Accountability	627	627	574
▪ Program Management	2,536	3,005	2,512

The Pacific Northwest National Laboratory (PNNL) Safeguards and Security 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 is the responsibility of the Office of Environmental Management.

Princeton Plasma Physics Laboratory	**2,128**	**2,128**	**2,149**
▪ Protective Forces	975	975	975
▪ Security Systems	20	20	20
▪ Cyber Security	795	795	816
▪ Program Management	338	338	338

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.

Stanford Linear Accelerator Center	**2,566**	**2,566**	**2,586**
▪ Protective Forces	1,897	1,897	1,916
▪ Cyber Security	669	669	670

The Stanford Linear Accelerator Center (SLAC) Safeguards and Security program focuses on reducing the risk to DOE national facilities and assets. SLAC provides the essential required safeguards and security programs while currently making improvements in the cyber security program due to increased Federal Information Security Management Act requirements and threats reporting from the Department of Homeland Security, National Cyber Security Division.

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
Thomas Jefferson National Accelerator Facility	**1,376**	**1,376**	**1,411**
▪ Protective Forces	695	695	695
▪ Security Systems	102	102	122
▪ Cyber Security	505	505	520
▪ Program Management	74	74	74

Thomas Jefferson National Accelerator Facility (TJNAF) conducts fundamental science research while providing support to federal government activities causing the need for federal level safeguard and security procedures. TJNAF has a guard force that provides 24-hour services for the accelerator site and after-hours property protection security for the entire site.

	FY 2007	FY 2008	FY 2009
All Other	**2,104**	**2,355**	**3,588**
▪ Security Systems	—	—	142
▪ Cyber Security	2,000	2,225	3,352
▪ Program Management	104	130	94

All Other supports the continuation and management of a consistent cyber security approach across the Office of Science laboratory complex and program management needs for SC. A portion of funding for security systems and cyber security will be allocated to sites based on highest priority needs following programmatic reviews.

	FY 2007	FY 2008	FY 2009
Subtotal, Safeguards and Security	**75,830**	**75,946**	**80,603**
Less Security Charge for Reimbursable Work	**-5,605**	**-5,605**	**—**
Total, Safeguards and Security	**70,225**	**70,341**	**80,603**

Explanation of Funding Changes

	FY 2009 vs. FY 2008 ($000)
Ames Laboratory	
Increased funding is provided for overall effectiveness of security operations with improvements and modernization of security systems.	+30
Argonne Laboratory	
Funding for cyber security increases to address infrastructure refresh, advancement of cyber security policy, computing protection, and two-factor authentication.	+35

	FY 2009 vs. FY 2008 ($000)
Brookhaven National Laboratory	
The funding increase is needed to provide enhanced protective force measures and required training ($+520,000) and for cyber security to provide for certifications, security testing and evaluation, enhanced intrusion detection system program, network access control, forensics, and upgrade spam filtering technology ($+183,000). Other minor adjustments will realign funding to the highest priority areas ($-86,000).	+617
Chicago Office	
The funding increase to personnel security addresses Homeland Security Presidential Directive-12 for the requirement of new employee identity cards and program enrollment stations.	+543
Fermi National Accelerator Laboratory	
The funding increase provides for essential security systems and program management needs.	+56
Lawrence Berkeley National Laboratory	
Increased funding is provided to improve overall safeguards and security effectiveness; funding is realigned to reflect the laboratory's safeguards and security priorities.	+21
Oak Ridge Institute for Science and Education	
The funding increase provides for required maintenance on security systems, and funding is realigned to highest safeguards and security priorities.	+38
Oak Ridge National Laboratory	
Security systems increases to provide for enhanced compatibility of communication equipment and to replace portions of aging security systems ($+433,000). Information security increases to reflect the high priority placed on this area due to incidents of security concern and inquiries ($+341,000). Funding for cyber security increases to implement authentication infrastructure, maintain accreditation and certification of cyber security master plans, and upgrade and maintain the technical infrastructure ($+235,000). Funding in other elements decreases to realign funds with program priorities ($-11,000).	+998
Oak Ridge Office	
The increase, primarily in protective forces, supports: a contractual pension contribution payment; replacement of radio equipment that will no longer be manufactured; upgrade of communication security devices due to technology changes for classified communication links; and required training.	+970
Office of Scientific and Technical Information	
The funding increase for cyber security provides the ability to address gaps identified by the SC Site Assistance Visit for an intrusion prevention system, mobile devices, and infrastructure support.	+20

	FY 2009 vs. FY 2008 ($000)
Pacific Northwest National Laboratory	
Funding is increased for security systems to provide upgrades to the closed circuit television ($+106,000); cyber security to maintain baseline compliance activities, implement classified diskless architecture, enable sustained cyber security operations and ability to respond to newly discovered vulnerabilities in systems, and implement cyber security upgrades due to technology advances and DOE requirements ($+440,000). Funding in other elements decreases to reflect the laboratory's safeguards and security priorities ($-526,000).	+20
Princeton Plasma Physics Laboratory	
The increase to cyber security provides for deployment and administration of an enterprise-wide encryption system for desktops, laptops, and removable media.	+21
Stanford Linear Accelerator Center	
The funding increase for protective forces will support emergency response units, as required.	+20
Thomas Jefferson National Accelerator Facility	
The increase for security systems will support purchases of video cameras and equipment ($+20,000). The increase for cyber security provides for the periodic replacement of cyber security protection and detection capability equipment to ensure continuing reliability ($+15,000).	+35
All Other	
The funding increases concentrate on cyber security and security systems. The need for obtaining a safe and secure cyber environment is a high requirement to prevent data corruption and cyber espionage. Funding will be allocated to sites based on priority needs following programmatic reviews for cyber security and security systems.	+1,233
Subtotal Funding Change, Safeguards and Security	**+4,657**
Security Charge for Reimbursable Work	
Beginning in FY 2009, all funding associated with safeguards and security charges at SC laboratories will be requested through direct appropriations. In FY 2008 and before, a portion of safeguards and security expenses was recovered through charges to reimbursable customers at the laboratories.	+5,605
Total Funding Change, Safeguards and Security	**+10,262**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)		
	FY 2007	FY 2008	FY 2009
General Plant Projects	322	—	—
Capital Equipment	195	110	—
Total, Capital Operating Expenses	517	110	—