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 **[**four**]** *forty-seven* passenger motor vehicles for replacement only, including not to exceed one ambulance, **[**$3,628,902,000**]** *and not to exceed two buses, $3,462,718,000,* to remain available until expended. *(Energy and Water Development Appropriations Act, 2005.)*

Explanation of Change

Changes are proposed to reflect the FY 2006 funding and vehicle request.

Science
Office of Science
Overview
Appropriation Summary by Program

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Science					
Basic Energy Sciences	991,262	1,113,530	-8,898[a]	1,104,632	1,146,017
Advanced Scientific Computing Research	196,795	234,340	-1,872[a]	232,468	207,055
Biological and Environmental Research	624,048	586,590	-4,678[a]	581,912	455,688
(One-time projects)	(136,798)	(80,250)	(-642)	(79,608)	(0)
(Other Biological and Environmental Research)	(487,250)	(506,340)	(-4,036)	(502,304)	(455,688)
High Energy Physics	716,170	742,380	-5,936[a]	736,444	713,933
Nuclear Physics	379,792	408,040	-3,262[a]	404,778	370,741
Fusion Energy Sciences	255,859	276,110	-2,207[a]	273,903	290,550
Science Laboratories Infrastructure	55,266	42,336	-338[a]	41,998	40,105
Science Program Direction	150,277[b]	155,268	-1,562[ab]	153,706	162,725
Workforce Development for Teachers and Scientists	6,432	7,660	-61[a]	7,599	7,192
Safeguards and Security	62,328	73,315	-542[a]	72,773	74,317
Small Business Innovation Research/Small Business Technology Transfer	114,915[c]	0	0	0	0
Subtotal, Science	3,553,144	3,639,569	-29,356	3,610,213	3,468,323
Less use of prior year balances	-11,173	-5,062	0	-5,062	0
Less security charge for reimbursable work	-5,598	-5,605	0	-5,605	-5,605
Total, Science	3,536,373	3,628,902	-29,356	3,599,546	3,462,718
(Total, excluding one-time projects)	(3,399,575)	(3,548,652)	(-28,714)	(3,519,938)	(3,462,718)

Preface

The Office of Science (SC) requests $3,462,718,000 for the Fiscal Year (FY) 2006 Science appropriation, a decrease of $136,828,000 from the FY 2005 appropriation, for investments in basic research that are critical to the success of Department of Energy (DOE) missions in national security and energy security; advancement of the frontiers of knowledge in the physical sciences and areas of biological, environmental, and computational sciences; and provision of world-class research facilities for the Nation's science enterprise.

The FY 2006 SC budget request supports the ITER and hydrogen fuel Presidential initiatives as well as other Administration priorities such as nanotechnology and climate change science research. ITER is funded within Fusion Energy Sciences (FES); the Hydrogen Fuel Initiative within Basic Energy

[a] Includes a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes a reduction of $313,000 in FY 2004 and $325,000 in FY 2005 for a comparability adjustment for FY 2006 savings from the A-76 Financial Services competition that are transferred to Departmental Administration.
[c] Includes $76,220,000 reprogrammed within SC and $38,695,000 transferred from other DOE programs.

Sciences (BES); nanotechnology within BES and Advanced Scientific Computing Research (ASCR); and climate change research within Biological and Environmental Research (BER).

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

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

Strategic Context

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

Department Mission → Strategic Goal (25 yrs) → General Goal (10–15 yrs) → Program Goal (GPRA Unit) (10–15 yrs)

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

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

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

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

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

The OMB-OSTP guidance memo to agencies dated August 12, 2004, describes the R&D investment criteria fully and identifies steps agencies should take to fulfill them. (The memo is available on line at http://www.ostp.gov/html/m04-23.pdf.) Where appropriate throughout these justification materials specific R&D investment criteria and requirements are cited to explain the Department's allocation of resources.

Mission

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

Benefits

SC represents an investment in our Nation's future. By providing support for key scientific disciplines, critical scientific tools, and the scientific workforce of today and tomorrow, we help to provide the foundation of our high-tech economy. The National Academies have stated that nearly half of all economic growth comes from investments in research. SC uses the principles of peer review, competition, transparency, and community involvement to guide our investments toward the most promising areas of science. We also look toward the future—not simply joining the latest trends but identifying emerging opportunities and pushing the limits of today's technology.

Our Strategic Plan and "Facilities for the Future of Science" 20-year outlook set an ambitious and clear agenda for scientific discovery over the next decade that reflects national priorities, the missions of the Department, and the views of the U.S. scientific community. Many of the fields we support count experiment time in years or even decades. In these areas, clear, consistent support is a key to success. Other areas change so rapidly that key publications are maintained electronically to keep pace. Flexibility is critical in these areas. Publishing long-range plans and priorities and implementing these through our annual budget request allows us to keep our research agenda clear and consistent while also being responsive to the changing opportunities at the forefront of research.

SC has proven its ability to deliver results over the past 50 years. That legacy includes 70 Nobel Laureates since 1954. Our science has spawned entire new industries, including nuclear medicine technologies that save thousands of lives each year, and the nuclear power industry that now contributes 20% of the power to our Nation's electricity grid. It has also changed the way we see the universe and ourselves; for example—by identifying the ubiquitous and mysterious "dark energy" that is accelerating the expansion of the universe and by sequencing the human genome. SC has taken the lead on new research challenges, such as bringing the power of terascale computing for scientific discovery and industrial competitiveness.

Strategic, General, and Program Goals

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

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

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

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

Program Goal 05.24.00.00: Bring the Power of the Stars to Earth—Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels our sun.

Program Goal 05.19.00.00: Explore the Fundamental Interactions of Energy, Matter, Time, and Space—Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe, search for possible new dimensions of space, and investigate the nature of time itself.

Program Goal 05.20.00.00: Explore Nuclear Matter, from Quarks to Stars—Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks, and gluons; to the stable elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability and possess radically different properties from known matter.

Program Goal 05.21.00.00: Harness the Power of Our Living World—Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and fundamentally change the nature of medical care to improve human health.

Program Goal 05.22.00.00: Advance the Basic Science for Energy Independence—Provide the scientific knowledge and tools to achieve energy independence, securing U.S. leadership and essential breakthroughs in basic energy sciences.

Program Goal 05.23.00.00: Deliver Computing for Accelerated Progress in Science—Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

Contribution to General Goals

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

ASCR program contributes to General Goal 5 by significantly advancing scientific simulation and computation; applying new approaches, algorithms, and software and hardware combinations to address the critical science challenges of the future; by providing access to world-class scientific computation and networking facilities to the Nation's scientific community to support advancements in practically every field of science and industry; and by providing platforms for virtual prototypes to enhance economic competitiveness for U.S. industry. ASCR will continue to advance the transformation of scientific simulation and computation into the third pillar of scientific discovery, enabling scientists to look inside an atom or across a galaxy; and inside a chemical reaction that takes a millionth of a billionth of a second or across a climate change process that lasts for a thousand years. In addition, ASCR will shrink the distance between scientists and the resources—experiments, data, and other scientists—they need, and accelerate scientific discovery by taking simulation times from years to days to hours.

BES contributes to General Goal 5 by advancing nanoscale science through atomic- and molecular-level studies in materials sciences and engineering, chemistry, geosciences, and energy biosciences. BES also provides the Nation's researchers with world-class research facilities, including reactor and accelerator-based neutron sources, light sources including the X-ray free electron laser currently under construction, and micro-characterization centers. These facilities provide outstanding capabilities for imaging and characterizing materials of all kinds from metals, alloys, and ceramics to fragile biological samples. The next steps in the characterization and the ultimate control of materials properties and chemical reactivity are to improve spatial resolution of imaging techniques; to enable a wide variety of samples, sample sizes, and sample environments to be used in imaging experiments; and to make measurements on very short time scales, comparable to the time of a chemical reaction or the formation of a chemical bond. With these tools, we will be able to understand how the composition of materials affects their properties, to watch proteins fold, to see chemical reactions, and to understand and observe the nature of the chemical bond. Theory, modeling, and computer simulations will also play a major role in achieving these outcomes and will be a companion to experimental work. BES is also implementing the opportunities contained in the study "Basic Research Needs to Assure a Secure Energy Future." A first example is the support of basic research aimed at advancing hydrogen production, storage, and use for the coming hydrogen economy. A second is an assessment of the basic research needs for effective solar energy conversion to electricity or fuels.

BER contributes to General Goal 5 by advancing energy-related biological and environmental research in genomics and our understanding of complete biological systems, such as microbes that produce hydrogen; by developing models to predict climate over decades to centuries; by developing science-based methods for cleaning up environmental contaminants; by providing regulators with a stronger scientific basis for developing future radiation protection standards; and by conducting limited research in medical imaging, including radiopharmaceuticals.

FES contributes to General Goal 5 by advancing the theoretical and experimental understanding of plasma and fusion science, including a close collaboration with international partners in identifying and exploring plasma and fusion physics issues through specialized facilities. This 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 of more attractive fusion energy sources in the long term; 5) focusing on the scientific issues of nonneutral plasma physics and High Energy Density Physics; and 6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals. The research capabilities are essential to the construction and operation of ITER; described below. FES also contributes to General Goal 5 through participation in ITER, an experiment to study and demonstrate the sustained burning of fusion fuel. This proposed international collaboration will provide an unparalleled scientific research opportunity with a goal of demonstrating the scientific and technical feasibility of fusion power. ITER is a multi-billion dollar international research project that will, if successful, advance progress towards developing fusion's potential as a commercially viable and clean source of energy near the middle of the century.

The FY 2006 Budget provides for the start in mid-FY 2006 of a Major Item of Equipment (MIE) project entitled "U.S. Contributions to ITER." This title draws distinction between the international ITER project, in which the U.S. will be one of many participating parties, and the MIE, for which the U.S. has specific responsibilities. The Total Project Cost, including Total Estimated Cost (TEC) and Other Project Costs (OPC), for the U.S. Contributions to ITER MIE is provided in detail in the budget for the FES program.

HEP contributes to General Goal 5 by advancing understanding of the basic constituents of matter, dark energy and dark matter, the lack of symmetry between matter and antimatter in the current universe, and the possible existence of other dimensions, collectively revealing key secrets of the universe. HEP expands the energy frontier with particle accelerators to study fundamental interactions at the highest possible energies, which may reveal new particles, new forces, or undiscovered dimensions of space and time; explain the origin of mass; and illuminate the pathway to the underlying simplicity of the universe. At the same time, the HEP program sheds new light on other mysteries of the cosmos, uncovering what holds galaxies together and what is pushing the universe apart; understanding why there is any matter in the universe at all; and exposing how the tiniest constituents of the universe may have the largest role in shaping its birth, growth, and ultimate fate.

NP contributes to General Goal 5 by supporting innovative, peer- reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, and, in particular, to investigate the fundamental forces that hold the nucleus together and determine the detailed structure and behavior of the atomic nuclei. The program builds and operates world-leading scientific facilities and state-of-the-art instrumentation to study 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 understand how the quarks and gluons combine to form the nucleons (proton and neutron), what the properties and behavior are of nuclear matter under extreme conditions of temperature and pressure, and what the properties and reaction rates are for atomic nuclei up to their limits of stability. Results and insight from these studies are relevant to understanding how the universe evolved in it earliest moments, how the chemical elements were formed, and how the properties of one of nature's basic constituents, the neutrino, influences astrophysics phenomena such as supernovae. Scientific discoveries at the frontiers of nuclear physics further the nation's energy-related research capacity, in turn providing for the nation's security, economic growth and opportunities, and improved quality of life.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.19.00.00, High Energy Physics	716,170	736,444	713,933
Program Goal 05.20.00.00, Nuclear Physics	379,792	404,778	370,741
Program Goal 05.21.00.00, Biological and Environmental Research	624,048	581,912	455,688
Program Goal 05.22.00.00, Basic Energy Sciences	991,262	1,104,632	1,146,017
Program Goal 05.23.00.00, Advanced Scientific Computing Research	196,795	232,468	207,055
Program Goal 05.24.00.00, Fusion Energy Sciences	255,859	273,903	290,550
Subtotal, General Goal 5, World-Class Scientific Research Capacity	3,163,926	3,334,137	3,183,984
All Other			
Science Laboratories Infrastructure	55,266	41,998	40,105
Program Direction	150,277	153,706	162,725
Workforce Development for Teachers and Scientists	6,432	7,599	7,192
Safeguards and Security	62,328	72,773	74,317
Small Business Innovation Research/Small Business Technology Transfer	114,915	0	0
Total, All Other	389,218	276,076	284,339
Total, General Goal 5 (Science)	3,553,144	3,610,213	3,468,323

Major FY 2004 Accomplishments

The 2003 Nobel Prize for Physics was shared by an Argonne National Laboratory researcher for pioneering contributions to the theory of superconductors. SC has long supported this work on the mechanisms of high temperature superconductivity. Amongst the myriad applications of superconducting materials are the magnets used for magnetic resonance imaging, or MRI, and potential applications in high efficiency electricity transmission and high-speed trains.

The 2004 Nobel Prize in Physics was awarded to three researchers (from MIT, University of California at Santa Barbara, and Caltech) for their discovery of “asymptotic freedom” in the theory of strong interactions, Quantum ChromoDynamics (QCD). This is the force that holds protons together. Their theoretical work was decisive in understanding one of Nature’s fundamental forces and made it possible to complete the Standard Model of Particle Physics, the model that describes the smallest objects in Nature and how they interact. Two of the three researchers have been supported by the HEP program for many years.

In 2004, the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory (BNL) delivered gold beams at twice the accelerator design limits and greatly exceeded the expectations of the 1,000-plus international physicists working on the four experiments at RHIC. The goal of RHIC is to recreate the predicted quark-gluon plasma, an extremely dense state of matter thought to have last existed microseconds after the Big Bang. The RHIC data have revealed evidence of a new state of matter, however, with properties which indicate that it is strongly interacting – something new and unexpected – as well as possible evidence of another state of matter, called the “color glass condensate.”

Program Assessment Rating Tool (PART)

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

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

SC did not complete PARTs for the FY 2006 Budget. In the FY 2005 PART review, OMB assessed six SC programs: ASCR, BES, BER, FES, HEP, and NP. Program scores ranged from 82-93%. Three programs—BES, BER, and NP—were assessed “Effective.” Three programs—ASCR, FES, and HEP—were assessed “Moderately Effective.” The full PARTs are available on the OMB website at http://www.whitehouse.gov/omb/budget/fy2005/part.html.

A Committee of Visitors (COV) is a panel of outside experts who review a program’s portfolio for quality and consistent application of business practices. Based on the success of the COV formed by the BES program, and as subsequently recommended by OMB in the FY 2005 PART findings, SC has established COVs for all six research programs. Each of these COVs conducted at least one review by the end of FY 2004. These COVs have been formed under the auspices of the programs’ Scientific Advisory Committees. Charge letters and reports for the COVs are on the SC website at http://www.science.doe.gov/measures/cov.html.

In addition, SC has taken steps to enhance public understanding of our revised performance measures. A PART website (http://www.science.doe.gov/measures/) has been developed to better explain what each scientific measure means, why it is important to the Department and/or the research community, and how progress will be measured. Roadmaps with more detailed information on tracking progress toward the long-term measures have been developed with the Scientific Advisory Committees and will be posted to this PART website. The Advisory Committees will review progress toward those measures vis-à-vis the roadmaps every 3 to 5 years. The first reviews will be conducted in FY 2007. The results of these reviews will be published on the PART website as they become available.

Significant Program Shifts

SC is ready to meet the challenges of today. We have established clear research priorities for the present and for the next decade. We have identified the key research facilities our Nation needs to build to maintain scientific excellence. We will restructure our workforce and our business practices to achieve greater efficiencies and economies of scale that will improve the performance of the 10 national laboratories that we manage. This budget request fully supports the SC workforce. Tough decisions have been made, but we are confident that the investments we propose are among the very best that science has to offer and are sound investments in our Nation's future.

In keeping with the R&D Investment Criteria's commitment to excellence through peer reviewed competition, ASCR will recompete major elements of its portfolio related to Scientific Discovery through Advanced Computing (SciDAC) in FY 2006, with attention paid to support for the long-term maintenance and support of software tools such as mathematical libraries, adaptive mesh refinement software, and scientific data management tools developed in the first 5 years of the effort. In addition, in FY 2006, ASCR is changing the way in which it manages its Genomics: GTL partnership with BER. The management of these efforts will be integrated into the portfolio of successful SciDAC partnerships. The FY 2006 budget request includes $7,500,000 for continued support of the Genomics: GTL research program, in partnership with BER; $2,600,000 for the Nanoscale Science, Engineering and Technology initiative led by the BES program; $1,350,000 for support of the Fusion Simulation Project, led by the FES program; and $8,500,000 to continue "Atomic to Macroscopic Mathematics" research support in applied mathematics needed to break through the current barriers in our understanding of complex physics processes that occur on a wide range of interacting length- and time-scales. Finally, in FY 2006 ASCR will initiate a small number of competitively selected SciDAC institutes at universities which can become centers of excellence in high end computational science in areas that are critical to DOE missions at a total funding level of $8,000,000. In keeping with the principles of the PART, the research effort in Collaboratory Tools and Pilots and Networking will be restructured into an integrated Distributed Network Environment activity focused on basic research in computer networks and the middleware needed to make these networks tools for science. The efficiencies achieved through this restructuring will enable the Next Generation Architecture (NGA) effort to operate computers, such as the 20 teraflop Cray X1e and Cray Red Storm system acquired in FY 2004 and FY 2005 at the Center for Computational Sciences (CCS) at the Oak Ridge National Laboratory (ORNL), as tools for science and especially to satisfy the demand for resources that has resulted from the successful SciDAC efforts. In addition, the NGA activity initiates a new competition for Research and Evaluation (R&E) prototype computer testbeds to enable SciDAC teams to evaluate the potential of future architectures. NGA will continue its focus on research in operating systems and systems software. These efforts are aligned with the plan developed by the National Science and Technology Council (NSTC). These efforts will play a critical role in enabling Leadership Class Machines that could lead to solutions for scientific and industrial problems beyond what would be attainable through a continued simple extrapolation of current computational capabilities. This area has been identified as a priority within the overall Networking and Information Technology Research and Development (NITR&D) priorities of the

Administration. Core funding for university and national laboratory researchers decreases 11.9% compared to the FY 2005 appropriation.

In BES, FY 2006 marks the completion of construction and the initial operation of the Spallation Neutron Source. Operations will also begin at four of the five Nanoscale Science Research Centers (NSRCs) with the exception being the Center for Functional Nanomaterials at BNL, which is scheduled to begin operations in FY 2008. NSRCs are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. The NSRCs are designed to promote rapid advances in the various areas of nanoscale science and technology and are part of the DOE contribution to the National Nanotechnology Initiative. The Linac Coherent Light Source (LCLS) will continue Project Engineering Design (PED) and will begin construction at the planned levels. Funding will be provided separately for preconceptual design of instruments for the facility. Funding will also be provided to partially support operation of the Stanford Linear Accelerator Center (SLAC) linac. This will mark the beginning of the transition to LCLS operations at SLAC. This new facility will open entirely new realms of discovery in the chemical, materials, and biological sciences. Pioneering developments of aberration-correcting electron optics have created the unprecedented opportunity to directly observe the atomic-scale order, electronic structure, and dynamics of individual nanoscale structures by advanced transmission electron microscopy. The FY 2006 budget supports an MIE for the Transmission Electron Aberration-corrected Microscope (TEAM). All BES construction projects are reviewed and monitored via an R&D Investment Criteria best practice for performance. To maintain progress toward a PART long-term goal, research to realize the potential of a hydrogen economy will be increased from $29,183,000 to $32,500,000. This research program is based on the BES workshop report Basic Research Needs for the Hydrogen Economy. Operations at the Radiochemical Engineering and Development Center at ORNL will be terminated. The operations budgets of the remaining facilities will be at about the same level as in FY 2005, decreasing available beam time and service for users. Core funding for university and national laboratory researchers decreases 7.8% compared to the FY 2005 appropriation. While no research activities will be terminated, there will be reductions throughout.

BER is investigating the potential for a new generation of sophisticated high-throughput genomics technologies, making them widely and readily available, and using them effectively to serve the community of national laboratories, and academic and industrial researchers. In keeping with the relevance principles in the R&D Investment Criteria, the Biological and Environmental Research Advisory Committee (BERAC) has confirmed that these Genomics: GTL facilities are highly relevant to the mission of BER and the goals of the research community. A high-level National Academies Study will be commissioned in FY 2005 to assess the scientific case for the Genomics: GTL effort as it relates to DOE core missions. Research to underpin the development and design of the technologies to be incorporated into the proposed Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags is currently being funded as part of the Genomics: GTL program. The Ethical, Legal, and Societal Issues program will include activities applicable to biotechnology and nanotechnology in cooperation with other SC programs. Moving the management of the National Institute for Global Environmental Change (NIGEC) from the University of California at Davis to BER will increase performance by reducing overhead costs and freeing up funds to support additional research that is highly relevant to DOE missions. This action has been confirmed by the BERAC COV, called for in the PART, for the Climate Change Research program. The number of NIGEC regional centers will also be reduced from six to four by holding an open competition for the four centers in keeping with the excellence principles of the R&D Investment Criteria. Based on their relevance to the BER long-term goals and higher BER priorities, funding reductions are initiated in the Medical Applications and Measurement Science Research subprogram which is refocused on advanced medical imaging technology, including radiopharmaceuticals for imaging, and on the Artificial Retina. Based on the BERAC COV findings for the Environmental Remediation Research subprogram, the research activities are integrated into a single program to increase the efficiency of the activities and better address the BER long-term goals in environmental remediation research. Core funding for university and national laboratory researchers decreases 10.2% compared to the FY 2005 appropriation.

In FES, the FY 2006 budget continues the redirection of the fusion program to prepare for and participate in the ITER program—an initiative taken at Presidential direction. Operation of the three major fusion research facilities will be reduced from a total of 48 weeks to 17 weeks. The TEC for the National Compact Stellarator Experiment (NCSX) increases. Other program shifts include reduction of the Inertial Fusion Energy/High Energy Density Physics program from the FY 2005 level. In addition, the Materials Research program will be eliminated in favor of reliance upon the general BES materials effort for U.S. scientific advances in areas of fusion interest. Overall, core funding for university, industry, and national laboratory researchers decreases by 12.8% compared to the FY 2005 appropriation. The FY 2006 request for the U.S. Contributions to ITER MIE is summarized in the following table.

U.S. Contributions to ITER
Annual Profile

(budget authority in thousands)

Fiscal Year	Total Estimated Cost	Other Project Costs	Total Project Cost
2006	46,000	3,500	49,500
2007	130,000	16,000	146,000
2008	182,000	18,800	200,800
2009	191,000	16,500	207,500
2010	189,000	10,300	199,300
2011	151,000	9,300	160,300
2012	120,000	6,200	126,200
2013	29,000	3,400	32,400
Total	1,038,000	84,000	1,122,000

Because of its broad relevance in addressing many of the long-term goals of HEP, and its unique potential for new discoveries, the highest priority is given to the planned operations for the Tevatron program at Fermi National Accelerator Laboratory, including fully funded upgrades and infrastructure support. To fully exploit the unique opportunity to expand our understanding of the asymmetry of matter and anti-matter in the universe, a high priority is given to the operations for the B-factory at SLAC, including an allowance for increased power costs, associated upgrades, and infrastructure support. With its great potential for discoveries, such as understanding of the origin of mass, support of a leadership role for U.S. research groups in the Large Hadron Collider (LHC) physics program will be a high priority. As the LHC accelerator in Geneva, Switzerland nears its turn-on, U.S. activities related to fabrication of detector and accelerator components will be completed and new activities related to commissioning, pre-operations, and software and computing will ramp-up significantly. Given the schedule and funding constraints, the BTeV (“B Physics at the Tevatron”) experiment, which was planned in FY 2005 as a new MIE, will be terminated by end of FY 2005. This is consistent with the guidance of the High Energy Physics Advisory Panel (HEPAP), which supported BTeV, but only if it could be completed by FY 2010. To explore the nature of dark energy, R&D for potential interagency experiments with the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA) will continue in FY 2006. To address the opportunity for significant new future research options, R&D in support of an international electron-positron linear collider is increased. To provide a nearer-term future program, and preserve future research options, R&D for other new accelerator and detector technologies, particularly in the emerging area of neutrino physics, will increase in FY 2006. Core funding for university and national laboratory researchers is about the same as the FY 2005 appropriation.

In NP, the FY 2006 budget request maintains the scientific scope of the nation's nuclear physics program. In keeping with PART findings and principles, termination of operations of the MIT/Bates facility in FY 2005 will allow resources for the remaining user facilities: the RHIC at BNL, the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Laboratory (TJNAF), and the Argonne Tandem Linear Accelerator System (ATLAS) and Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL. Operations at these facilities will be at about 65% of optimum utilization. Investments are made in capabilities at these facilities to extract the desired science and to improve efficiencies in the outyears. The R&D Investment Criteria's relevance principles recommend utilizing community planning in establishing program priorities. FY 2006 funding for capital equipment will address opportunities identified in the 2002 Nuclear Science Advisory Committee (NSAC) Long Range Plan and subsequent NSAC recommendations. At RHIC, funding is provided for needed detector upgrades, redirecting modest funds available for operations of the facility and existing detectors. At TJNAF, funding is provided for 12 GeV CEBAF Upgrade R&D and conceptual design activities. At ATLAS and HRIBF, the priority is on emphasizing facility operations within available funds. The research programs at the major user facilities are integrated partnerships between DOE scientific laboratories and the university community, and the planned experimental research activities are considered essential for scientific productivity of the facilities. Core funding for university and national laboratory researchers decreases 9.3% compared to the FY 2005 appropriation. R&D activities for the proposed Rare Isotope Accelerator (RIA) are maintained at the FY 2005 Presidential Request level.

The purpose of the S&S program is to ensure appropriate levels of protection against unauthorized access, theft, diversion, loss of custody or destruction of DOE assets, and hostile acts that may cause adverse impacts on fundamental science, national security, or the health and safety of DOE and contractor employees, the public, or the environment. In FY 2006, small increases in funding are primarily for security systems for reconfiguration and improvements of entry points at BNL and SLAC and for revised Design Basis Threat needs primarily at ORNL.

The SLI mission is to enable the conduct of Departmental research missions at the ten SC laboratories and the Oak Ridge Institute for Science and Education (ORISE) by funding line item construction to maintain the general purpose infrastructure and the clean-up and removal of excess facilities. The program also supports SC landlord responsibilities for the 34,000 acre Oak Ridge Reservation; provides Payment in Lieu of Taxes (PILT); and provides for the correction of Occupational Safety and Health Administration (OSHA) and Nuclear Regulatory Commission identified deficiencies and implementation of recommendations for improved health and safety practices at SC laboratories. In FY 2006, the SLI program will initiate the clean-up and removal of the retired Bevatron accelerator at the Lawrence Berkeley National Laboratory.

The SCPD mission is to provide a Federal workforce, skilled and highly motivated, to manage and support basic energy and science-related research disciplines, diversely supported through research programs, projects, and facilities under the SC's leadership. Rollout of Phase 1 of the SC restructuring initiative (OneSC) was announced in March 2004. The new SC structure improves organizational and functional alignment, reporting relationships (by reducing layers of management), streamlining decision-making processes, clarifying lines of authority, and making better use of resources. Phase 2 of OneSC will occur over the next 24 months and involves human capital and organizational analyses and reengineering of SC business and management operations and processes. This phase will optimize SC business practices, take unnecessary work out of the system, enable the federal workforce to be more productive, support improved laboratory contractor performance, and ultimately drive down the cost of doing business in both federal and contractor operations. This project embraces the changes envisioned by the PMA to manage government programs more economically and effectively.

WDTS will run Laboratory Science Teacher Professional Development (LSTPD) activities at five or more DOE national laboratories with about 105 participating teachers, in response to the national need for science teachers who have strong content knowledge in the classes they teach. FY 2006 represents the third year of this program and 15 new teachers will be supported, in addition to the 90 teachers already part-way through this 3-year program. The Faculty Sabbatical activity, which begins in FY 2005 for 12 faculty members from Minority Serving Institutions, will have 5 positions available in FY 2006. The Pre-Service Teachers activity will be run at one national laboratory, and students will be recruited from participating NSF programs. On July 8, 2004, DOE announced the STARS education initiative to promote science literacy and help develop the next generation of scientists and engineers. In support of this effort, there is additional funding to both the LSTPD activity and to the Middle School Science Bowl. The components of the STARS that involve educational outreach by national laboratory scientists and engineers to middle school students will be executed by the national laboratories through their respective workforce development/education offices.

Institutional General Plant Projects

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

Examples of prior year and current year projects are:

- Building 1506 Renovation at ORNL. This FY 2003 and FY 2004 effort included structural upgrades to comply with DOE and international codes; greenhouse replacements; laboratory reconfigurations; and heating, ventilation and air conditioning (HVAC) modifications. TEC: $3,150,000.
- East Campus Entry and Parking design and construction at ORNL. This effort, initiated in FY 2003, includes construction of a new 25,000 square foot parking court for approximately 60 cars and a 20,000 square foot terrace area with seating and informal gathering areas. TEC: $2,467,000.
- Quadrangle Common Area design and construction at ORNL. This FY 2004 and FY 2005 effort includes lawn, landscaping, sidewalks, lighting, and street improvements to an area of approximately 71,000 square feet. TEC: $2,697,000.
- 5000 Area Utility Systems Upgrade at ORNL. This FY 2005 project will provide utility services (i.e., natural gas, potable water, and sanitary sewer) for the East Campus area to support new third party development. TEC: $325,000.
- Horn Rapids Triangle Utilities Infrastructure at the Pacific Northwest National Laboratory. This FY 2005 and FY 2006 project will provide the needed site utility infrastructure to support the

proposed construction of new lab and office facilities to replace 300 Area facilities which will be demolished. Area to be developed is approximately 70 acres. TEC: $3,500,000.

The following displays IGPP funding by site:

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Oak Ridge National Laboratory	6,000	8,000	8,000	0	0.0%
Pacific Northwest National Laboratory	500	5,000	5,000	0	0.0%
Total, IGPP	6,500	13,000	13,000	0	0.0%

Selected Office of Science Activities

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Hydrogen Initiative	7,710	29,183	32,500	+3,317	+11.4%
Genomics: GTL	73,177	84,984	94,686	+9,702	+11.4%
Climate Change Science Program	129,328	128,570	132,109	+3,539	+2.8%
High Performance Computing and Communications	213,035	252,932	227,434	-25,498	-10.1%
Nanoscience Engineering and Technology	201,582	210,415	207,481	-2,934	-1.4%
ITER	0	0	49,500	+49,500	--

Science
Office of Science
Funding by Site by Program

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Ames Site Office					
Ames Laboratory					
Basic Energy Sciences	21,050	19,921	19,274	-647	-3.2%
Advanced Scientific Computing Research	2,232	1,409	1,227	-182	-12.9%
Biological and Environmental Research	1,005	400	0	-400	-100.0%
Science Laboratories Infrastructure	425	210	45	-165	-78.6%
Safeguards and Security	409	505	505	0	0.0%
Workforce Development for Teachers and Scientists	0	65	65	0	0.0%
Total, Ames Laboratory	25,121	22,510	21,116	-1,394	-6.2%
Ames Site Office					
Science Program Direction	355	443	453	+10	+2.3%
Total, Ames Site Office	25,476	22,953	21,569	-1,384	-6.0%
Argonne Site Office					
Argonne National Laboratory – East					
Basic Energy Sciences	175,280	174,714	182,213	+7,499	+4.3%
Advanced Scientific Computing Research	12,696	12,733	8,319	-4,414	-34.7%
Biological and Environmental Research	27,595	26,884	27,154	+270	+1.0%
High Energy Physics	10,491	10,162	9,989	-173	-1.7%
Nuclear Physics	20,242	19,710	17,749	-1,961	-9.9%
Fusion Energy Sciences	1,015	971	970	-1	-0.1%
Science Laboratories Infrastructure	6,921	2,235	770	-1,465	-65.5%
Workforce Development for Teachers and Scientists	1,913	867	2,483	+1,616	+186.4%
Safeguards and Security	7,655	8,727	8,984	+257	+2.9%
Total, Argonne National Laboratory	263,808	257,003	258,631	+1,628	+0.6%
Argonne Site Office					
Science Program Direction	2,990	3,596	3,677	+81	+2.3%
Total, Argonne Site Office	266,798	260,599	262,308	+1,709	+0.7%

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Berkeley Site Office					
Lawrence Berkeley National Laboratory					
Basic Energy Sciences	126,172	123,828	105,113	-18,715	-15.1%
Advanced Scientific Computing Research	63,934	69,268	63,783	-5,485	-7.9%
Biological and Environmental Research	75,417	68,444	59,974	-8,470	-12.4%
High Energy Physics	43,439	40,131	39,300	-831	-2.1%
Nuclear Physics	18,236	17,350	17,437	+87	+0.5%
Fusion Energy Sciences	5,842	6,112	2,613	-3,499	-57.2%
Science Laboratories Infrastructure	4,455	8,199	14,826	+6,627	+80.8%
Workforce Development for Teachers and Scientists	773	454	638	+184	+40.5%
Safeguards and Security	4,689	5,785	5,205	-580	-10.0%
Total, Lawrence Berkeley National Laboratory	342,957	339,571	308,889	-30,682	-9.0%
Berkeley Site Office					
Science Program Direction	2,433	3,302	3,305	+3	+0.1%
Total, Berkeley Site Office	345,390	342,873	312,194	-30,679	-8.9%
Brookhaven Site Office					
Brookhaven National Laboratory					
Basic Energy Sciences	69,842	83,720	100,844	+17,124	+20.5%
Advanced Scientific Computing Research	2,340	1,000	670	-330	-33.0%
Biological and Environmental Research	21,344	21,246	17,171	-4,075	-19.2%
High Energy Physics	30,456	29,459	29,041	-418	-1.4%
Nuclear Physics	149,626	157,086	148,150	-8,936	-5.7%
Science Laboratories Infrastructure	6,978	7,706	4,246	-3,460	-44.9%
Workforce Development for Teachers and Scientists	538	464	683	+219	+47.2%
Safeguards and Security	10,760	11,335	11,776	+441	+3.9%
Total, Brookhaven National Laboratory	291,884	312,016	312,581	+565	+0.2%
Brookhaven Site Office					
Science Program Direction	2,960	3,456	3,537	+81	+2.3%
Total, Brookhaven Site Office	294,844	315,472	316,118	+646	+0.2%

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Chicago Office					
Basic Energy Sciences	157,563	123,914	137,220	+13,306	+10.7%
Advanced Scientific Computing Research	34,718	31,489	25,119	-6,370	-20.2%
Biological and Environmental Research	278,248	114,422	87,339	-27,083	-23.7%
High Energy Physics	124,964	118,719	112,047	-6,672	-5.6%
Nuclear Physics	73,128	69,385	58,612	-10,773	-15.5%
Fusion Energy Sciences	125,596	131,797	125,581	-6,216	-4.7%
Science Laboratories Infrastructure	1,057	1,520	1,520	0	0.0%
Science Program Direction	23,991	23,979	25,406	+1,427	+6.0%
Workforce Development for Teachers and Scientists	2	0	15	+15	--
Small Business Innovation Research/Small Business Technology Transfer	114,915	0	0	0	0.0%
Total, Chicago Office	934,182	615,225	572,859	-42,366	-6.9%
Fermi Site Office					
Fermi National Accelerator Laboratory					
Advanced Scientific Computing Research	646	646	200	-446	-69.0%
High Energy Physics	311,764	303,608	304,163	+555	+0.2%
Nuclear Physics	43	0	0	0	0.0%
Science Laboratories Infrastructure	633	662	125	-537	-81.1%
Workforce Development for Teachers and Scientists	70	62	50	-12	-19.4%
Safeguards and Security	2,837	3,067	3,067	0	0.0%
Total, Fermi National Accelerator Laboratory	315,993	308,045	307,605	-440	-0.1%
Fermi Site Office					
Science Program Direction	2,175	2,189	2,235	+46	+2.1%
Total, Fermi Site Office	318,168	310,234	309,840	-394	-0.1%
Idaho Operations Office					
Idaho National Laboratory					
Basic Energy Sciences	1,142	253	555	+302	+119.4%
Biological and Environmental Research	4,555	3,645	2,250	-1,395	-38.3%
Fusion Energy Sciences	2,108	2,469	2,272	-197	-8.0%
Workforce Development for Teachers and Scientists	90	76	50	-26	-34.2%
Total, Idaho National Laboratory	7,895	6,443	5,127	-1,316	-20.4%
Idaho Operations Office					
Biological and Environmental Research	5,336	1,123	0	-1,123	-100.0%
Total, Idaho Operations Office	13,231	7,566	5,127	-2,439	-32.2%

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Livermore Site Office					
Lawrence Livermore National Laboratory					
Basic Energy Sciences	4,612	3,055	2,382	-673	-22.0%
Advanced Scientific Computing Research	5,657	6,187	3,843	-2,344	-37.9%
Biological and Environmental Research	22,391	23,183	22,352	-831	-3.6%
High Energy Physics	2,295	1,270	436	-834	-65.7%
Nuclear Physics	1,002	665	552	-113	-17.0%
Fusion Energy Sciences	14,431	13,503	9,159	-4,344	-32.2%
Science Laboratories Infrastructure	250	150	150	0	0.0%
Workforce Development for Teachers and Scientists	0	50	50	0	0.0%
Total, Livermore Site Office	50,638	48,063	38,924	-9,139	-19.0%
Los Alamos Site Office					
Los Alamos National Laboratory					
Basic Energy Sciences	33,664	28,924	24,406	-4,518	-15.6%
Advanced Scientific Computing Research	3,688	3,590	3,260	-330	-9.2%
Biological and Environmental Research	23,700	19,178	17,331	-1,847	-9.6%
High Energy Physics	785	570	825	+255	+44.7%
Nuclear Physics	10,080	9,081	7,953	-1,128	-12.4%
Fusion Energy Sciences	3,923	3,481	3,224	-257	-7.4%
Workforce Development for Teachers and Scientists	0	50	50	0	0.0%
Total, Los Alamos Site Office	75,840	64,874	57,049	-7,825	-12.1%
NNSA Service Center/Albuquerque					
Golden Field Office					
Workforce Development for Teachers and Scientists	359	296	380	+84	+28.4%
National Renewable Energy Laboratory					
Basic Energy Sciences	5,905	6,115	5,452	-663	-10.8%
Advanced Scientific Computing Research	150	150	150	0	0.0%
Biological and Environmental Research	25	400	0	-400	-100.0%
Total, National Renewable Energy Laboratory	6,080	6,665	5,602	-1,063	-15.9%
NNSA Service Center/Albuquerque					
Biological and Environmental Research	850	850	800	-50	-5.9%
Total, NNSA Service Center/Albuquerque	7,289	7,811	6,782	-1,029	-13.2%
NNSA Service Center/Oakland					
Fusion Energy Sciences	2,414	0	0	0	0.0%

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Oak Ridge Office					
Oak Ridge Institute for Science and Education					
Basic Energy Sciences	1,503	538	1,251	+713	+132.5%
Advanced Scientific Computing Research	565	250	250	0	0.0%
Biological and Environmental Research	4,410	4,628	3,675	-953	-20.6%
High Energy Physics	180	0	135	+135	--
Nuclear Physics	1,033	662	646	-16	-2.4%
Fusion Energy Sciences	1,086	1,189	1,228	+39	+3.3%
Science Laboratories Infrastructure	0	565	768	+203	+35.9%
Workforce Development for Teachers and Scientists	1,148	1,164	1,239	+75	+6.4%
Safeguards and Security	1,179	1,410	1,460	+50	+3.5%
Total, Oak Ridge Institute for Science and Education	11,104	10,406	10,652	+246	+2.4%
Oak Ridge National Laboratory					
Basic Energy Sciences	285,371	257,081	278,743	+21,662	+8.4%
Advanced Scientific Computing Research	52,902	67,052	30,937	-36,115	-53.9%
Biological and Environmental Research	47,093	41,529	33,175	-8,354	-20.1%
High Energy Physics	731	220	627	+407	+185.0%
Nuclear Physics	21,598	20,157	19,700	-457	-2.3%
Fusion Energy Sciences	22,506	20,727	15,782	-4,945	-23.9%
Science Laboratories Infrastructure	15,360	2,179	1,133	-1,046	-48.0%
Safeguards and Security	7,004	11,997	12,485	+488	+4.1%
Total, Oak Ridge National Laboratory	452,565	420,942	392,582	-28,360	-6.7%
Oak Ridge Office					
Basic Energy Sciences	123	106	0	-106	-100.0%
Advanced Scientific Computing Research	116	116	116	0	0.0%
Biological and Environmental Research	815	694	703	+9	+1.3%
High Energy Physics	122	106	0	-106	-100.0%
Nuclear Physics	167	106	0	-106	-100.0%
Fusion Energy Sciences	16	106	0	-106	-100.0%
Science Laboratories Infrastructure	5,049	5,039	5,079	+40	+0.8%
Science Program Direction	41,290	41,922	43,758	+1,836	+4.4%
Workforce Development for Teachers and Scientists	80	90	90	0	0.0%
Safeguards and Security	11,718	12,858	13,705	+847	+6.6%
Total, Oak Ridge Office	59,496	61,143	63,451	+2,308	+3.8%
Total, Oak Ridge Office	523,165	492,491	466,685	-25,806	-5.2%

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Pacific Northwest Site Office					
Pacific Northwest National Laboratory					
Basic Energy Sciences	14,018	13,345	13,429	+84	+0.6%
Advanced Scientific Computing Research	4,568	2,616	1,126	-1,490	-57.0%
Biological and Environmental Research	89,893	84,319	82,114	-2,205	-2.6%
Nuclear Physics	70	0	0	0	0.0%
Fusion Energy Sciences	1,380	1,314	0	-1,314	-100.0%
Science Laboratories Infrastructure	1	4,960	3,000	-1,960	-39.5%
Workforce Development for Teachers and Scientists	940	574	761	+187	+32.6%
Safeguards and Security	10,721	10,985	11,070	+85	+0.8%
Total, Pacific Northwest National Laboratory	121,591	118,113	111,500	-6,613	-5.6%
Pacific Northwest Site Office					
Science Program Direction	4,245	5,277	5,438	+161	+3.1%
Total, Pacific Northwest Site Office	125,836	123,390	116,938	-6,452	-5.2%
Princeton Site Office					
Princeton Plasma Physics Laboratory					
Advanced Scientific Computing Research	225	531	306	-225	-42.4%
High Energy Physics	225	225	225	0	0.0%
Fusion Energy Sciences	71,546	74,191	113,280	+39,089	+52.7%
Science Laboratories Infrastructure	1,580	184	0	-184	-100.0%
Workforce Development for Teachers and Scientists	80	134	100	-34	-25.4%
Safeguards and Security	1,855	1,945	1,945	0	0.0%
Total, Princeton Plasma Physics Laboratory	75,511	77,210	115,856	+38,646	+50.1%
Princeton Site Office					
Science Program Direction	1,505	1,583	1,618	+35	+2.2%
Total, Princeton Site Office	77,016	78,793	117,474	+38,681	+49.1%
Sandia Site Office					
Sandia National Laboratories					
Basic Energy Sciences	47,885	49,689	42,603	-7,086	-14.3%
Advanced Scientific Computing Research	9,422	10,127	4,544	-5,583	-55.1%
Biological and Environmental Research	7,384	6,732	4,530	-2,202	-32.7%
Fusion Energy Sciences	3,367	3,735	3,516	-219	-5.9%
Total, Sandia Site Office	68,058	70,283	55,193	-15,090	-21.5%

(dollars in thousands)	FY 2004	FY 2005	FY 2006	$ Change	% Change
Savannah River Site					
Westinghouse - Savannah River					
Biological and Environmental Research	823	773	654	-119	-15.4%
Fusion Energy Sciences	45	37	40	+3	+8.1%
Total, Westinghouse – Savannah River	868	810	694	-116	-14.3%
Savannah River Operations Office					
Biological and Environmental Research	7,599	7,748	0	-7,748	-100.0%
Total, Savannah River Site	8,467	8,558	694	-7,864	-91.9%
Stanford Site Office					
Stanford Linear Accelerator Center					
Basic Energy Sciences	45,076	91,378	152,609	+61,231	+67.0%
Advanced Scientific Computing Research	1,554	485	300	-185	-38.1%
Biological and Environmental Research	3,958	3,450	4,350	+900	+26.1%
High Energy Physics	166,426	166,192	143,951	-22,241	-13.4%
Science Laboratories Infrastructure	2,746	2,775	5,443	+2,668	+96.1%
Workforce Development for Teachers and Scientists	150	150	130	-20	-13.3%
Safeguards and Security	2,214	2,341	2,511	+170	+7.3%
Total, Stanford Linear Accelerator Center	222,124	266,771	309,294	+42,523	+15.9%
Stanford Site Office					
Science Program Direction	1,045	1,655	1,709	+54	+3.3%
Total, Stanford Site Office	223,169	268,426	311,003	+42,577	+15.9%
Thomas Jefferson Site Office					
Thomas Jefferson National Accelerator Facility					
Advanced Scientific Computing Research	300	0	0	0	0.0%
Biological and Environmental Research	891	525	400	-125	-23.8%
High Energy Physics	110	0	0	0	0.0%
Nuclear Physics	83,292	85,946	78,988	-6,958	-8.1%
Science Laboratories Infrastructure	9,357	0	0	0	0.0%
Workforce Development for Teachers and Scientists	289	136	250	+114	+83.8%
Safeguards and Security	972	1,474	1,224	-250	-17.0%
Total, Thomas Jefferson National Accelerator Facility	95,211	88,081	80,862	-7,219	-8.2%
Thomas Jefferson Site Office					
Science Program Direction	1,030	1,407	1,457	+50	+3.6%
Total, Thomas Jefferson Site Office	96,241	89,488	82,319	-7,169	-8.0%

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Washington Headquarters					
Basic Energy Sciences	2,056	128,051	79,923	-48,128	-37.6%
Advanced Scientific Computing Research	1,082	24,819	62,905	+38,086	+153.5%
Biological and Environmental Research	716	151,739	91,716	-60,023	-39.6%
High Energy Physics	24,182	65,782	73,194	+7,412	+11.3%
Nuclear Physics	1,275	24,630	20,954	-3,676	-14.9%
Fusion Energy Sciences	584	14,271	12,885	-1,386	-9.7%
Science Laboratories Infrastructure	454	5,614	3,000	-2,614	-46.6%
Science Program Direction	66,258	64,897	70,132	+5,235	+8.1%
Workforce Development for Teachers and Scientists	0	2,967	158	-2,809	-94.7%
Safeguards and Security	315	344	380	+36	+10.5%
Total, Washington Headquarters	96,922	483,114	415,247	-67,867	-14.0%
Total, Science	3,553,144	3,610,213	3,468,323	-141,890	-3.9%

Site Description

Ames Site Office

Introduction

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

Ames Laboratory

Introduction

The Ames Laboratory is a program dedicated laboratory (Basic Energy Sciences). The laboratory is located on the campus of the Iowa State University, in Ames, Iowa, and consists of 10 buildings (324,500 gross square feet of space) with the average age of the buildings being 40 years. DOE does not own the land. Ames conducts fundamental research in the physical, chemical, and mathematical sciences associated with energy generation and storage and is a national center for the synthesis, analysis, and engineering of rare-earth metals and their compounds.

Basic Energy Sciences

Ames supports experimental and theoretical research on rare earth elements in novel mechanical, magnetic, and superconducting materials. Ames scientists are experts on magnets, superconductors, and quasicrystals that incorporate rare earth elements. Ames also supports theoretical studies for the prediction of molecular energetics and chemical reaction rates and provides leadership in analytical and separations chemistry.

Ames is home to the **Materials Preparation Center (MPC)**, which is dedicated to the preparation, purification, and characterization of rare-earth, alkaline-earth, and refractory metal and oxide materials. Established in 1981, the MPC is a one-of-a-kind resource that provides scientists at university, industrial, and government laboratories with research and developmental quantities of high purity materials and unique analytical and characterization services that are not available from commercial suppliers. The MPC is renowned for its technical expertise in alloy design and for creating materials that exhibit ultrafine microstructures, high strength, magnetism, and high conductivity.

Advanced Scientific Computing Research

Ames conducts research in computer science and participates on one of the Scientific Discovery through Advanced Computing (SciDAC) teams. Ames also participates in Integrated Software Infrastructure Center activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

Ames conducts research into new biological imaging techniques such as the study of gene expression in real time and fluorescence spectroscopy to study environmental carcinogens.

Science Laboratories Infrastructure

The Science Laboratories Infrastructure (SLI) program enables Departmental research missions at the laboratory by funding line item construction and general plants projects (GPP) to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with Occupational Safety and Health Administration (OSHA) requirements.

Safeguards and Security

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

Argonne Site Office

Introduction

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

Argonne National Laboratory

Introduction

The Argonne National Laboratory in Argonne, Illinois, is a multiprogram laboratory located on 1,700 acres in suburban Chicago. The laboratory consists of 99 buildings (4.5 million gross square feet of space) with an average building age of 33 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 Intense Pulsed Neutron Source (IPNS), and the Electron Microscopy Center for Materials Research (EMC).

The **Advanced Photon Source** is one of only three third-generation, hard x-ray synchrotron radiation light sources in the world. The 1,104-meter circumference facility—large enough to house a baseball park in its center—includes 34 bending magnets and 34 insertion devices, which generate a capacity of 68 beamlines for experimental research. Instruments on these beamlines attract researchers to study the structure and properties of materials in a variety of disciplines, including condensed matter physics, materials sciences, chemistry, geosciences, structural biology, medical imaging, and environmental sciences. The high-quality, reliable x-ray beams at the APS have already brought about new discoveries in materials structure.

The **Intense Pulsed Neutron Source** is a short-pulsed spallation neutron source that first operated all of its instruments in the user mode in 1981. Twelve neutron beam lines serve 14 instruments. Distinguishing characteristics of IPNS include its innovative instrumentation and source technology and its dedication to serving the users. The first generation of virtually every pulsed source neutron scattering instrument was developed at IPNS. In addition, the source and moderator technologies developed at IPNS, including uranium targets, liquid hydrogen and methane moderators, solid methane moderators, and decoupled reflectors, have impacted spallation sources worldwide. Research at IPNS is conducted on the structure of high-temperature superconductors, alloys, composites, polymers, catalysts, liquids and non-crystalline materials, materials for advanced energy technologies, and biological materials.

The **Electron Microscopy Center for Materials Research** provides *in-situ*, high-voltage and intermediate voltage, high-spatial resolution electron microscope capabilities for direct observation of ion-solid interactions during irradiation of samples with high-energy ion beams. The EMC employs both a tandem accelerator and an ion implanter in conjunction with a transmission electron microscope for simultaneous ion irradiation and electron beam microcharacterization. It is the only instrumentation of its type in the western hemisphere. The unique combination of two ion accelerators and an electron microscope permits direct, real-time, *in-situ* observation of the effects of ion bombardment of materials and consequently attracts users from around the world. Research at EMC includes microscopy based studies on high-temperature superconducting materials, irradiation effects in metals and semiconductors, phase transformations, and processing related structure and chemistry of interfaces in thin films.

Advanced Scientific Computing Research

ANL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. ANL also participates in several scientific applications and participates on a number of the SciDAC teams. Further, it focuses on testing and evaluating leading edge research computers and participates in Integrated Software Infrastructure Center (ISIC) activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

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

High Energy Physics

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

Nuclear Physics

The major ANL activity is the operation and research and development 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); programs at Thomas Jefferson National Accelerator Facility (TJNAF), Fermi National Laboratory (Fermilab), Relativistic Heavy Ion Collider (RHIC) and DESY in Germany investigating the structure of the nucleon; R&D directed towards the proposed Rare Isotope Accelerator (RIA) facility; theoretical calculations and investigations in subjects supporting the experimental research programs in Medium Energy and Low Energy physics; and data compilation and evaluation activities as part of the National Nuclear Data Program.

The **Argonne Tandem Linac Accelerator System** facility provides variable energy, precision beams of stable ions from protons through uranium, at energies near the Coulomb barrier (up to 10 MeV per nucleon) using a superconducting linear accelerator. Most work is performed with stable heavy-ion beams; however, about 10% of the beams are exotic (radioactive) beams. The ATLAS facility features a wide array of experimental instrumentation, including a world-leading ion-trap apparatus, the Advanced Penning Trap. The Gammasphere detector, coupled with the Fragment Mass Analyzer, is a unique world facility for measurement of nuclei at the limits of angular momentum (high-spin states). ATLAS staff are world leaders in superconducting linear accelerator technology, with particular application to the proposed RIA facility. The combination of versatile beams and powerful instruments enables ~230 users annually at ATLAS to conduct research in a broad program in nuclear structure and dynamics, nuclear astrophysics, and fundamental interaction studies.

Fusion Energy Sciences

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

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements. The SLI program also provides Payments in Lieu of Taxes (PILT) to local communities around the laboratory.

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

Berkeley Site Office

Introduction

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

Lawrence Berkeley National Laboratory

Introduction

The Lawrence Berkeley National Laboratory is a multiprogram laboratory located in Berkeley, California, on a 200-acre site adjacent to the Berkeley campus of the University of California. The laboratory consists of 106 buildings (1.6 million gross square feet of space) with an average building age of 35 years. LBNL is dedicated to performing leading-edge research in the biological, physical, materials, chemical, energy, and computer sciences. The land is leased from the University of California.

Basic Energy Sciences

LBNL is home to major research efforts in materials and chemical sciences as well as to efforts in geosciences, engineering, and biosciences. Collocated with the University of California at Berkeley, the Laboratory benefits from regular collaborations and joint appointments with numerous outstanding faculty members. The Laboratory is the home to the research of many students and postdoctoral appointees. It is also the site of two Basic Energy Sciences (BES) supported user facilities — the Advanced Light Source (ALS) 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.

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.

Advanced Scientific Computing Research

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

Biological and Environmental Research

LBNL is one of the major national laboratory partners forming the Joint Genome Institute (JGI) whose principal goals are high-throughput DNA sequencing techniques and studies on the biological functions associated with the newly sequenced human DNA. The laboratory also conducts research on the molecular mechanisms of cell responses to low doses of radiation, on the use of model organisms to understand and characterize the human genome, and on microbial systems biology research as part of Genomics:GTL. LBNL operates beam lines for determination of protein structure at the ALS for use by the national and international biological research community. The ALS is also used by a growing environmental science community. The nuclear medicine program supports research into novel radiopharmaceuticals for medical diagnosis and therapy and studies of novel instrumentation for imaging of living systems for medical diagnosis. LBNL also supports the environmental remediation sciences research and the geophysical and biophysical research capabilities for field sites in that program.

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

High Energy Physics

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

Nuclear Physics

The Low Energy subprogram has supported operations and the research program of the 88-Inch Cyclotron, whose operations transitioned in FY 2004 to a dedicated in-house facility with partial operational support from other federal agencies to carry out their programs. Other activities include fabrication of a next-generation gamma-ray detector system, GRETINA; research with the STAR detector located at Brookhaven’s RHIC facility, operation of the Parallel Distributed Systems Facility aimed at heavy-ion and low energy physics computation, and a smaller research and development activity directed towards the ALICE detector within the heavy-ion program at the Large Hadron Collider at CERN; operation of the Sudbury Neutrino Observatory (SNO) detector in Canada and the KamLAND detector in Japan that are performing neutrino studies; development of next generation neutrino detectors; a program with emphasis on the theory of relativistic heavy-ion physics; data compilation and evaluation activities supporting the National Nuclear Data Center at BNL; and a technical effort in RIA R&D with the development of electron-cyclotron resonance (ECR) ion sources.

Fusion Energy Sciences

LBNL has been conducting research into the physics of generating, injecting, transporting, and focusing of high-brightness heavy ion beams for applications to inertial fusion energy in the long term. It has developed three substantial experimental systems for doing this research: the Neutralized Transport Experiment, the High Current Experiment, and the Ion Source Test Stand. The program is currently being redirected to focus on developing ion beams and beam-target interaction physics for applications to high energy density physics in the near term (5 to 10 years). LBNL conducts this research together with the Lawrence Livermore National Laboratory and Princeton Plasma Physics Laboratory (PPPL) through the Heavy-Ion Fusion Virtual National Laboratory.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

Safeguards and Security

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

Brookhaven Site Office

Introduction

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

Brookhaven National Laboratory

Introduction

The Brookhaven National Laboratory is a multiprogram laboratory located on 5,300 acres in Upton, New York. The laboratory consists of 345 buildings (3.9 million gross square feet of space) with an average building age of 35 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 major research efforts in materials and chemical sciences as well as to efforts in geosciences and biosciences. It is also the site of the National Synchrotron Light Source (NSLS).

The **National Synchrotron Light Source** (NSLS) is among the largest and most diverse scientific user facilities in the world. The NSLS, commissioned in 1982, has consistently operated at >95% reliability 24 hours a day, 7 days a week, with scheduled periods for maintenance and machine studies. Adding to its breadth is the fact that the NSLS consists of two distinct electron storage rings. The x-ray storage ring is 170 meters in circumference and can accommodate 60 beamlines or experimental stations, and the vacuum-ultraviolet (VUV) storage ring can provide 25 additional beamlines around its circumference of 51 meters. Synchrotron light from the x-ray ring is used to determine the atomic structure of materials using diffraction, absorption, and imaging techniques. Experiments at the VUV ring help solve the atomic and electronic structure as well as the magnetic properties of a wide array of materials. These data are fundamentally important to virtually all of the physical and life sciences as well as providing immensely useful information for practical applications. The petroleum industry, for example, uses the NSLS to develop new catalysts for refining crude oil and making by-products like plastics.

Advanced Scientific Computing Research

BNL conducts basic research in applied mathematics and participates on one of the SciDAC teams. It also participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

BNL operates beam lines for protein crystallography at the NSLS for use by the national biological research community, research in biological structure determination, and research into new instrumentation for detecting x-rays and neutrons. Research is also conducted on the molecular mechanisms of cell responses to low doses of radiation.

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

BNL is participating in the NSF/DOE Environmental Molecular Sciences Institute at State University of New York-Stony Brook and has instituted a new internal initiative EnviroSuite to support a growing community of environmental users at NSLS.

High Energy Physics

The HEP program supports physics research and technology R&D at BNL, using unique resources of the laboratory, including engineering and detector technology, superconducting magnet R&D, computational resources, and the Accelerator Test Facility.

Nuclear Physics

Research activities include use of relativistic heavy-ion beams and polarized protons in the Relativistic Heavy Ion Collider (RHIC) to investigate hot, dense nuclear matter and to understand the internal "spin" structure of the proton, respectively; use of polarized photon beams by the Laser Electron Gamma Source (LEGS) group to carry out a program of photonuclear spin physics at the NSLS; research on the properties of neutrinos at the Sudbury Neutrino Observatory (SNO); and data compilation and evaluation at the National Nuclear Data Center (NNDC) that is the central U.S. site for these national and international efforts.

The **Relativistic Heavy Ion Collider** Facility, completed in 1999, is a major unique international facility currently used by about 1,000 scientists from 19 countries. RHIC uses the Tandem Van de Graaff, Booster Synchrotron, and Alternating Gradient Synchrotron (AGS) accelerators in combination to inject beams into two rings of superconducting magnets of almost 4 kilometers circumference with 6 intersection regions where the beams can collide. It can accelerate and collide a variety of heavy ions, including gold beams, up to an energy of 100 GeV per nucleon. RHIC is being used to search for the predicted "quark-gluon plasma," a form of nuclear matter thought to have existed microseconds after the "Big Bang." It can also collide polarized protons with beams of energy up to 250 GeV per nucleon: a unique capability. Four detectors have been fabricated to provide complementary measurements, with some overlap in order to cross-calibrate the measurements. (1) The core of the Solenoidal Tracker at RHIC (STAR) detector is a large Time Projection Chamber (TPC) located inside a solenoidal magnet that tracks thousands of charged particles emanating from a single head-on gold-gold collision. A large modular barrel Electro-Magnetic Calorimeter (EMCal) and end-cap calorimeter measure deposited energy for high-energy charged and neutral particles and contain particle-photon discrimination capability. Other ancillary detector systems include a Silicon Vertex Tracker and forward particle tracking capabilities. (2) The Pioneering High-Energy Nuclear Interacting eXperiment (PHENIX) detector has a particular focus on the measurement of rare probes at high event detection rate. It consists of two transverse spectrometer arms that can track charged particles within a magnetic field, especially to higher momentum: it provides excellent discrimination among photons, electrons, and hadrons. There are also two large muon tracking and identification systems in the forward and backward directions as well as ancillary tracker systems. (3) The Phobos detector is a very compact detector that uses mostly silicon pad sensors for charged particle detection and tracking, with a focus on measurements to very low momentum. (4) The Broad RAnge Hadron Magnetic Spectrometer (BRAHMS) has two small acceptance magnetic spectrometer arms that can be rotated to scan the broadest range of angles, designed to study the charged-particle distributions especially in the forward direction. International participation has been essential in the implantation of all these 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. Operation of the AGS for fixed target experiments is planned through the recently approved Rare Symmetry Violating Processes (RSVP) program being supported by the National Science Foundation (NSF). 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 **National Nuclear Data Center (NNDC)** is the central U.S. site for national and international nuclear data and compilation efforts. The U.S. Nuclear Data program is the United States' repository for information generated in low- and intermediate-energy nuclear physics research worldwide. This information consists of both bibliographic and numeric data. The NNDC is a resource for a very broad user community in all aspects of nuclear technology, with relevance to homeland security. Nuclear Data program-funded scientists at U.S. national laboratories and universities contribute to the activities and responsibilities of the NNDC.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements. The SLI program also provides PILT to local communities around the laboratory.

Safeguards and Security

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

Chicago Office

Introduction

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

Basic Energy Sciences

The BES program funds research at 168 colleges/universities located in 48 states.

Advanced Scientific Computing Research

The Advanced Scientific Computing Research (ASCR) program funds research at 71 colleges/universities located in 24 states supporting approximately 126 principal investigators.

Biological and Environmental Research

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

High Energy Physics

The HEP program supports about 260 research groups at more than 100 colleges and universities located in 36 states, Washington, D.C., and Puerto Rico. The strength and effectiveness of the university-based program is critically important to the success of the program as a whole.

Nuclear Physics

The Nuclear Physics (NP) program funds 185 research grants at 85 colleges/universities located in 35 states. Among these are grants with the Triangle Universities Nuclear Laboratory (TUNL); Texas A&M (TAMU) Cyclotron; the Yale Tandem Van de Graaff; the University of Washington Tandem Van de Graaff; and a cooperative agreement with the Massachusetts Institute of Technology (MIT). These accelerator facilities offer niche capabilities and opportunities not available at the national user facilities, or many foreign low-energy laboratories, such as specialized sources and targets, opportunities for extended experiments, and specialized instrumentation. Also supported is the Institute for Nuclear Theory (INT) at the University of Washington, a premier international center for new initiatives and collaborations in nuclear theory research.

Fusion Energy Sciences

The Fusion Energy Sciences (FES) program funds research at more than 50 colleges and universities located in approximately 30 states. FES also funds the DIII-D tokamak experiment and related programs at GA, an industrial firm located in San Diego, California.

Fermi Site Office

Introduction

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

Fermi National Accelerator Laboratory

Introduction

Fermi National Accelerator Laboratory (Fermilab) is a program-dedicated laboratory (High Energy Physics) located on a 6,800-acre site in Batavia, Illinois. The laboratory consists of 348 buildings (2.3 million gross square feet of space) with an average building age of 38 years. Fermilab is the largest U.S. laboratory for research in high-energy physics and is second only to CERN, the European Laboratory for Particle Physics. About 2,500 scientific users, scientists from universities and laboratories throughout the U.S. and around the world, use Fermilab for their research. Fermilab's mission is the goal of high-energy physics: to understand matter at its deepest level, to identify its fundamental building blocks, and to understand how the laws of nature determine their interactions.

Advanced Scientific Computing Research

Fermilab conducts research in the network environment for science.

High Energy Physics

Fermilab operates the Tevatron accelerator and colliding beam facility, which consists of a four-mile ring of superconducting magnets and two large multi-purpose detectors, and is capable of accelerating protons and antiprotons to an energy of one trillion electron volts (1 TeV). The Tevatron is the highest energy proton accelerator in the world, and will remain so until the Large Hadron Collider begins commissioning at the European Organization for Nuclear Research (CERN) in 2007. With the shutdown of the Large Electron-Positron (LEP) collider at CERN in 2000, the Tevatron became the only operating particle accelerator at the energy frontier. The Tevatron complex also includes the Booster and the Main Injector, pre-accelerators to the Tevatron. The Main Injector, which is used for the pre-acceleration of protons and production of antiprotons as a part of the Tevatron complex, will also be used independently of the Tevatron for a 120 GeV fixed target program, including the Neutrinos at the Main Injector (NuMI) beamline which starts operation in 2005. The Booster is used to accelerate low-energy protons, and a small part of the beam that is not used for Tevatron collider operations is provided to produce neutrinos for short-baseline oscillation experiments. Fermilab is the principal experimental facility for HEP. The HEP program also supports physics research and technology R&D at Fermilab, using unique resources of the laboratory, including engineering and detector technology, superconducting magnet R&D, and computational resources.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

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, security systems, and material control and accountability programs to accurately account for and protect the facility's special nuclear materials. Limited funding increases would be applied to security systems and the Foreign Visits and Assignments program.

Idaho Operations Office

Idaho National Laboratory

Introduction

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

Basic Energy Sciences

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

Biological and Environmental Research

Using unique DOE capabilities such as advanced software for controlling neutron beams and calculating dose, INL supports research into boron chemistry, radiation dosimetry, analytical chemistry of boron in tissues, and engineering of new computational systems for application of radiation treatment to tumors, including brain tumors. BER support for Boron Neutron Capture Therapy dosimetry and support programs at INL and the core programs to determine boronconcentrations in biologic specimens will terminate in FY 2005. INL is also conducting research in subsurface science relating to clean up of the nuclear weapons complex.

Fusion Energy Sciences

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

Livermore Site Office

Lawrence Livermore National Laboratory

Introduction

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

Basic Energy Sciences

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

Advanced Scientific Computing Research

LLNL participates in base applied mathematics and computer science research and SciDAC efforts. It also participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

LLNL is one of the major national laboratory partners that comprise the Joint Genome Institute (JGI) whose principal goals are high-throughput DNA sequencing and studies on the biological functions associated with newly sequenced human DNA. LLNL is developing new biocompatible materials and microelectronics for the artificial retina project. It also conducts research on the molecular mechanisms of cell responses to low doses of radiation, and on the use of model organisms to understand and characterize the human genome.

Through the program for Climate Model Diagnosis and Intercomparison, LLNL provides the international leadership to develop and apply diagnostic tools to evaluate the performance of climate models and to improve them. Virtually every climate modeling center in the world participates in this unique program. It also conducts research to improve understanding of the climate system, particularly the climate effect of clouds and related processes.

High Energy Physics

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

Nuclear Physics

The LLNL program supports research in experimental and theoretical nuclear structure studies, for relativistic heavy-ion experiments as part of the PHENIX collaboration, for nuclear data and compilation activities, and for a technical effort involved in RIA R&D.

Fusion Energy Sciences

LLNL works with LBNL and PPPL through the Heavy-Ion Fusion Virtual National Laboratory in advancing the physics of heavy ion beams as a driver for inertial fusion energy in the long term and high energy density physics in the near term. It also conducts research in the concept of Fast Ignition for applications in high energy density physics and inertial fusion energy. The LLNL program also includes collaborations with General Atomics on the DIII-D tokamak, operation of an innovative concept experiment, the Sustained Spheromak Physics Experiment at LLNL, and benchmarking of fusion physics computer models with experiments such as DIII-D. It carries out research in the simulation of turbulence and its effect on transport of heat and particles in magnetically confined plasmas.

Science Laboratories Infrastructure

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

Los Alamos Site Office

Los Alamos National Laboratory

Introduction

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

Basic Energy Sciences

LANL is home to selected research 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.

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

Advanced Scientific Computing Research

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

Biological and Environmental Research

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

LANL provides the site manager for the Tropical Western Pacific ARM site. LANL also has a crucial role in the development, optimization, and validation of coupled atmospheric and oceanic general circulation models using massively parallel computers. LANL also conducts research into advanced medical imaging technologies for studying brain function including optical imaging and magnetoencepholography, novel radionuclide dosimetry and therapy, and research into new techniques for rapid characterization and sorting of mixtures of cells and cell fragments. LANL also conducts research under environmental remediation sciences.

High Energy Physics

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

Nuclear Physics

NP supports a broad program of research including: a program of neutron beam research that utilizes beams from LANSCE facility to make fundamental physics measurements; the development of an experiment to search for the electric dipole moment of the neutron; a research and development effort in relativistic heavy-ions using the PHENIX detector at the RHIC and development of next generation instrumentation for RHIC; research directed at the study of the quark substructure of the nucleon in experiments at Fermilab, and the "spin" structure of nucleons at RHIC using polarized proton beams; research at the Sudbury Neutrino Observatory (SNO) and at MiniBooNE directed at studies of the properties of neutrinos including development of the next generation detector; a broad program of theoretical research; nuclear data and compilation activities as part of the national nuclear data program; and a technical effort involved in RIA R&D.

Fusion Energy Sciences

LANL supports the creation of computer codes for modeling the stability of magnetically confined plasmas, including tokamaks and innovative confinement concepts. The work provides also 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, Washington. LANL is also investigating innovative confinement concepts such as Magnetized Target Fusion and Inertial Electrostatic Confinement. LANL also supports the tritium processing activities needed for ITER.

NNSA Service Center/Albuquerque

National Renewable Energy Laboratory

Introduction

The National Renewable Energy Laboratory (NREL) is a program-dedicated laboratory (Solar) located on 300 acres in Golden, Colorado. NREL was built to emphasize renewable energy technologies such as photovoltaics and other means of exploiting solar energy. It is the world leader in renewable energy technology development. Since its inception in 1977, NREL's sole mission has been to develop renewable energy and energy efficiency technologies and transfer these technologies to the private sector.

Basic Energy Sciences

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

Oak Ridge Office

Introduction

The Oak Ridge Office (ORO) directly provides corporate support (i.e., procurement, legal, finance, budget, human resources, and facilities and infrastructure) to site offices responsible for program management oversight of two major management and operating laboratories: PNNL and TJNAF. Oak Ridge also oversees the Oak Ridge Reservation and other DOE facilities in the City of Oak Ridge. Together on the Reservation and in the City of Oak Ridge there are 26 buildings (363,000 square feet) with a total replacement plant value (RPV) of $29.2 million. The RPV of the roads and other structures on the Reservation is $48.3 million. As a result of the recent A-76 competition for financial services, the Oak Ridge Financial Service Center provides payment services for the entire Department of Energy/NNSA, nation-wide. The administrative, business and technical expertise of Oak Ridge is shared SC-wide through the Integrated Support Center concept. The ORO Manager is also the single Federal official with responsibility for contract performance at ORNL and the Oak Ridge Institute for Science and Education (ORISE). The Manager provides on-site presence for ORNL and ORISE with authority encompassing contract management, program and project implementation, Federal stewardship, and internal operations.

Science Laboratories Infrastructure

The Oak Ridge Landlord subprogram provides for centralized ORO infrastructure requirements and general operating costs for activities (e.g., roads) on the Oak Ridge Reservation outside plant fences plus DOE facilities in the town of Oak Ridge, PILT, and other needs related to landlord activities.

Safeguards and Security

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

Oak Ridge Institute for Science and Education

Introduction

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

Basic Energy Sciences

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

Advanced Scientific Computing Research

ORISE provides support for education activities.

Biological and Environmental Research

ORISE coordinates research fellowship programs and manages the DOE-NSF program supporting graduate students to attend the Lindau Meeting of Nobel Laureates. It also coordinates activities associated with the peer review of most of the submitted research proposals. ORISE also conducts research into modeling radiation dosages for novel clinical diagnostic and therapeutic procedures.

High Energy Physics

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

Nuclear Physics

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

Fusion Energy Sciences

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

Science Laboratories Infrastructure

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

Science Program Direction

ORISE facilitates and coordinates communication and outreach activities, and conducts studies on workforce trends in the sciences.

Safeguards and Security

The S&S program at ORISE provides physical protection/protective force services by employing unarmed security officers. The facilities are designated as property protection areas for the purpose of protecting government-owned assets. In addition to the government-owned facilities and personal property, ORISE possesses small quantities of nuclear materials that must be protected. The program includes information security, personnel security, protective forces, security systems, and cyber security.

Oak Ridge National Laboratory

Introduction

The Oak Ridge National Laboratory is a multiprogram laboratory located on 24,000 acres in Oak Ridge, Tennessee. The laboratory's 1,100 acre main site on Bethel Valley Road contains 302 buildings (3.4 million gross square feet of space) with an average building age of 32 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 research and development 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. It is the site of the High Flux Isotope Reactor (HFIR). ORNL also is the site of SNS, which is under construction and scheduled for commissioning in FY 2006. ORNL has perhaps the most comprehensive materials research program in the country.

The **High Flux Isotope Reactor** is a light-water cooled and moderated reactor that began full-power operations in 1966. HFIR operates at 85 megawatts to provide state-of-the-art facilities for neutron scattering, materials irradiation, and neutron activation analysis and is the world's leading source of elements heavier than plutonium for research, medicine, and industrial applications. The neutron scattering experiments at HFIR reveal the structure and dynamics of a very wide range of materials. The neutron-scattering instruments installed on the four horizontal beam tubes are used in fundamental studies of materials of interest to solid-state physicists, chemists, biologists, polymer scientists, metallurgists, and colloid scientists. Recently, a number of improvements at HFIR have increased its neutron scattering capabilities to 14 state-of-the-art neutron scattering instruments on the world's brightest beams of steady-state neutrons. These upgrades include the installation of larger beam tubes and shutters, a high-performance liquid hydrogen cold source, and neutron scattering instrumentation.

Advanced Scientific Computing Research

ORNL conducts basic research in the mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. It also participates in several scientific application and collaboratory pilot projects and participates on a number of the SciDAC teams. Advanced Computing Research Testbeds (ACRT) are focused on the evaluation of leading edge research computers. Integrated Software Infrastructure Center activities are focused on specific software challenges confronting users of terascale computers. The Center for Computational Sciences (CCS), located at ORNL, provides high-end capability computing services to SciDAC teams and other DOE users. ORNL was selected by DOE to develop leadership-class computing capability for science to revitalize the U.S. effort in high end computing.

Biological and Environmental Research

ORNL has a leadership role in research focused on the ecological aspects of global environmental change. The Throughput Displacement Experiment at the Walker Branch Watershed is a unique resource for long-term ecological experiments. 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 scientists provide improvement in formulations and numerical methods necessary to improve climate models. ORNL scientists make important contributions to the environmental remediation sciences research programs, providing special leadership in microbiology applied in the field. ORNL also manages the environmental remediation sciences research Field Research Center, a field site for developing and testing bioremediation methods for metal and radionuclide contaminants in subsurface environments. ORNL, in conjunction with ANL and PNNL and six universities, plays a principle role in the CSiTE consortium which is focusing on research to enhance the capacity, rates, and longevity of carbon sequestration in terrestrial ecosystems.

ORNL conducts research on widely used data analysis tools and information resources that can be automated to provide information on the biological function of newly discovered genes identified in high-throughput DNA sequencing projects. ORNL conducts microbial systems biology research as part of Genomics:GTL. The laboratory also operates the Laboratory for Comparative and Functional Genomics, or “Mouse House,” which uses mice as model organisms to understand and characterize the human genome. The laboratory is developing a new experimental station for biological small angle neutron scattering. ORNL conducts research into the application of radioactively labeled monoclonal antibodies in medical diagnosis and therapy, particularly of cancer, as well as research into new instrumentation for the analytical chemistry of complex environmental contamination using new types of biosensors.

High Energy Physics

The HEP program supports a small research effort using unique capabilities of ORNL primarily in the area of particle beam shielding calculations. Through the SciDAC program, HEP also supports an effort at ORNL to model the physics processes that drive supernova explosions.

Nuclear Physics

The major effort at ORNL is the research, development, and operations of the HRIBF that is operated as a national user facility. Also supported are a relativistic heavy-ion group that is involved in a research program using the PHENIX detector at RHIC; the development of the Fundamental Neutron Physics Beamline at SNS; a theoretical nuclear physics effort that emphasizes investigations of nuclear structure and astrophysics; nuclear data and compilation activities that support the national nuclear data effort; and a technical effort involved in RIA R&D.

The **Holifield Radioactive Ion Beam Facility** is the only radioactive nuclear beam facility in the U.S. to use the isotope separator on-line (ISOL) method and is used annually by about 90 scientists for studies in nuclear structure, dynamics and astrophysics using radioactive beams. The HRIBF accelerates secondary radioactive beams to higher energies (up to 10 MeV per nucleon) than any other facility in the world with a broad selection of ions. The HRIBF conducts R&D on ion sources and low energy ion transport for radioactive beams.

Fusion Energy Sciences

ORNL develops a broad range of components that are critical for improving the research capability of fusion experiments located at other institutions and that are essential for developing fusion as an environmentally acceptable energy source. The laboratory is a leader in the theory of heating of plasmas by electromagnetic waves, antenna design, and design and modeling of pellet injectors to fuel the plasma and control the density of plasma particles. The laboratory is also the site of the Controlled Fusion Atomic Data Center and its supporting research programs. While some ORNL scientists are located full-time at off-site locations, others carry out their collaborations with short visits to the host institutions, followed by extensive computer communications from ORNL for data analysis and interpretation, and theoretical studies. ORNL is also a leader in stellarator theory and design and is a major partner with PPPL on the National Compact Stellarator Experiment (NCSX) being built at PPPL. ORNL, in partnership with PPPL, shares responsibility for managing the U.S. ITER Project Office, effective July 2004. ORNL has led the fusion materials science program, which is planned for termination in FY 2006.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

Safeguards and Security

The S&S program includes security systems, information security, cyber security, personnel security, material control and accountability, and program management. Program planning functions at the laboratory provide for short- and long-range strategic planning, and special safeguards plans associated with both day-to-day protection of site-wide security interests and preparation for contingency operations. Additionally, ORNL is responsible for providing overall laboratory policy direction and oversight in the security arena; for conducting recurring programmatic self-assessments; for assuring a viable ORNL Foreign Ownership, Control or Influence (FOCI) program is in place; and for identifying, tracking, and obtaining closure on findings or deficiencies noted during inspections, surveys, or assessments of S&S programs.

Office of Scientific and Technical Information

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

Pacific Northwest Site Office

Introduction

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

Pacific Northwest National Laboratory

Introduction

Pacific Northwest National Laboratory is a multiprogram laboratory located on 132 acres at the Department's Hanford site in Richland, Washington. The laboratory consists of one government-owned building (200,000 gross square feet of space) with the average age of the building being 7 years. PNNL conducts research in the area of environmental science and technology and carries out related national security, energy, and human health

Basic Energy Sciences

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

Advanced Scientific Computing Research

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

Biological and Environmental Research

PNNL is home to the William R. Wiley **Environmental Molecular Sciences Laboratory (EMSL),** a national user facility. PNNL scientists, including EMSL scientists, play important roles in performing environmental remediation sciences research for the National and Accelerated Bioremediation Research (NABIR) and Environmental Management Science Program (EMSP). PNNL operates the unique ultrahigh field mass spectrometry and nuclear magnetic resonance spectrometry instruments at the EMSL for use by the national research community.

PNNL provides the G-1 research aircraft, and expertise in field campaigns for atmospheric sampling and analysis. The ARM program office is located at PNNL, as is the ARM chief scientist and the project manager for the ARM engineering activity; this provides invaluable logistical, technical, and scientific expertise for the program. It also conducts research into new instrumentation for microscopic imaging of biological systems and for characterization of complex radioactive contaminants by highly automated instruments.

PNNL 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.

PNNL, in conjunction with ANL and ORNL and six universities, plays an important role in the CSiTE consortium, focusing on the role of soil microbial processes in carbon sequestration. PNNL also conducts research on the integrated assessment of global climate change.

Fusion Energy Sciences

PNNL has focused on research on materials that can survive in a fusion neutron environment. Experienced scientists and engineers at PNNL provide leadership in the evaluation of ceramic matrix composites for fusion applications and support work on vanadium, copper, and ferrite steels as part of the U.S. fusion materials team. These programs are planned for closeout in FY 2006. Another PNNL activity for FES is a small scale study of future fusion energy requirements.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

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.

Princeton Site Office

Introduction

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

Princeton Plasma Physics Laboratory

Introduction

Princeton Plasma Physics Laboratory is a program-dedicated laboratory (Fusion Energy Sciences) located on 88.5 acres in Plainsboro, New Jersey. The laboratory consists of 38 buildings (725,000 gross square feet of space) with an average building age of 29 years. DOE does not own the land.

Advanced Scientific Computing Research

PPPL participates in a collaboratory pilot project and several SciDAC projects.

High Energy Physics

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

Fusion Energy Sciences

PPPL is the only U.S. Department of Energy (DOE) laboratory devoted primarily to plasma and fusion science. The laboratory hosts experimental facilities used by multi-institutional research teams and also sends researchers and specialized equipment to other fusion facilities in the United States and abroad. PPPL is the host for the NSTX, which is an innovative toroidal confinement device, closely related to the tokamak, and has started construction of another innovative toroidal concept, the NCSX, a compact stellarator. PPPL scientists and engineers have significant involvement in the DIII-D and Alcator C-Mod tokamaks and the NSF Center for Magnetic Self-Organization in Laboratory and Astrophysical Plasmas in the U.S. and several large tokamak facilities abroad, including JET (Europe), JT-60U (Japan), and

KSTAR (Korea). This research is focused on developing the scientific understanding and innovations required for an attractive fusion energy source. PPPL scientists are also involved in several basic plasma science experiments, ranging from magnetic reconnection to plasma processing. PPPL also has a large theory group that does research in the areas of turbulence and transport, equilibrium and stability, wave-plasma interaction, and heavy ion accelerator physics. PPPL, LBNL, and LLNL currently work together in advancing the physics of heavy ion drivers through the heavy ion beams Fusion Virtual National Laboratory. Effective July 2004, PPPL, in partnership with ORNL, was selected to manage the U.S. ITER Project Office. Through its association with Princeton University, PPPL provides high quality education in fusion-related sciences, having produced more than 185 Ph.D. graduates since its founding in 1951.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

Safeguards and Security

The S&S program provides for protection of nuclear materials, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, or other hostile acts. These activities result in reduced risk to national security and the health and safety of DOE and contractor employees, the public, and the environment.

Sandia Site Office

Sandia National Laboratories

Introduction

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

Basic Energy Sciences

SNL is home to significant research efforts in materials and chemical sciences with additional programs in engineering and geosciences. SNL/CA is also the site of the Combustion Research Facility (CRF). SNL has a historic emphasis on electronic components needed for Defense Programs. The laboratory has very modern facilities in which unusual microcircuits and structures can be fabricated out of various semiconductors.

The **Combustion Research Facility** at SNL/CA is an internationally recognized facility for the study of combustion science and technology. In-house efforts combine theory, modeling, and experiment including diagnostic development, kinetics, and dynamics. Several innovative non-intrusive optical diagnostics such as degenerate four-wave mixing, cavity ring-down spectroscopies, high resolution optical spectroscopy, and ion-imaging techniques have been developed to characterize combustion intermediates. Basic research is often conducted in close collaboration with applied programs. A principal effort in turbulent combustion is coordinated among the chemical physics program, and programs in Fossil Energy and Energy Efficiency and Renewable Energy.

Advanced Scientific Computing Research

SNL conducts basic research in mathematics and computer science, as well as research in advanced computing software tools and collaboratory tools. It also participates in several scientific application and collaboratory pilot projects, participates on a number of the SciDAC teams, and participates in ISIC activities that focus on specific software challenges confronting users of terascale computers.

Biological and Environmental Research

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

To support environmental cleanup, SNL conducts research into novel sensors for analytical chemistry of contaminated environments. It also conducts computational and biological research in support of the Genomics:GTL research program.

Fusion Energy Sciences

Sandia plays a lead role in developing components for fusion devices through the study of plasma interactions with materials, the behavior of materials exposed to high heat fluxes, and the interface of plasmas and the walls of fusion devices. It selects, specifies, and develops materials for components exposed to high heat and particles fluxes and conducts extensive analysis of prototypes to qualify components before their use in fusion devices. Materials samples and prototypes are tested in Sandia's Plasma Materials Test Facility, which uses high-power electron beams to simulate the high heat fluxes expected in fusion environments. Materials and components are exposed to tritium-containing plasmas in the Tritium Plasma Experiment located in the STAR facility at INL. Tested materials are characterized using Sandia's accelerator facilities for ion beam analysis. Sandia supports a wide variety of domestic and international experiments in the areas of tritium inventory removal, materials postmortem analysis, diagnostics development, and component design and testing. Sandia also works with LBNL through the Heavy Ion-Fusion Virtual National Laboratory in developing high-brightness ion source and other science issues of heavy ion beams. Sandia serves an important role in the design and analysis activities related to the ITER first wall components, including related R&D.

Savannah River Site

Introduction

The Savannah River Site complex covers 198,344 acres, or 310 square miles encompassing parts of Aiken, Barnwell and Allendale counties in South Carolina bordering the Savannah River.

Biological and Environmental Research

SRS hosts the Savannah River Ecology Laboratory (SREL), a research unit of the University of Georgia operating at the site for over 50 years. SREL conducts research aimed at understanding the ecological impacts of DOE contamination and cleanup efforts. SREL is supported through a cooperative agreement with the University of Georgia.

Savannah River National Laboratory

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

Biological and Environmental Research

SRNL scientists make important contributions to the EMSP program, providing leadership on high level waste issues of importance to SRS, and generally relating to clean up of the nuclear weapons complex.

Stanford Site Office

Introduction

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

Stanford Linear Accelerator Center

Introduction

The Stanford Linear Accelerator Center (SLAC) is located on 426 acres of Stanford University land in Menlo Park, California, and is also the home of the Stanford Synchrotron Radiation Laboratory (SSRL). The facility is now comprised of 25 experimental stations and is used each year by over 700 researchers from industry, government laboratories and universities. SLAC (including SSRL) consists of 166 buildings (1.9 million gross square feet of space) with the average age of 30 years. SLAC is a laboratory dedicated to the design, construction and operation of state-of-the-art electron accelerators and related experimental facilities for use in high-energy physics and synchrotron radiation research. SLAC operates the 2 mile long Stanford Linear Accelerator which began operating in 1966. The SSRL was built in 1974 to utilize the intense x-ray beams from the Stanford Positron Electron Accelerating Ring (SPEAR) that was built for particle physics by the SLAC laboratory. Over the years, SSRL grew to be one of the main innovators in the production and use of synchrotron radiation with the development of wigglers and undulators that form the basis of all third generation synchrotron sources.

Basic Energy Sciences

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

Advanced Scientific Computing Research

SLAC participates on a number of SciDAC teams.

Biological and Environmental Research

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

High Energy Physics

SLAC operates the **B-factory** and its detector, BaBar, and a small program of experiments in accelerator science and technology. The B-factory, a high energy electron-positron collider, was constructed to support a search for and high-precision study of CP symmetry violation in the B meson system. All of these facilities make use of the two-mile long linear accelerator, or linac. SLAC and Fermilab are the principal experimental facilities of the HEP program. The HEP program also supports physics research and technology R&D at SLAC, using unique resources of the laboratory, including engineering and detector technology, advanced accelerator technology, and computational resources.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

Safeguards and Security

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

Thomas Jefferson Site Office

Introduction

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.

Thomas Jefferson National Accelerator Facility

Introduction

Thomas Jefferson National Accelerator Facility is a program-dedicated laboratory (Nuclear Physics) located on 200 acres in Newport News, Virginia dedicated to the exploration of nuclear and nucleon structure. The laboratory consists of 62 buildings (407,000 gross square feet of space) with an average building age of 13 years. Constructed over the period FY 1987-1995 at a cost of $513,000,000, TJNAF began operations in FY 1995.

Biological and Environmental Research

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

High Energy Physics

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

Nuclear Physics

The centerpiece of TJNAF is the **Continuous Electron Beam Accelerator Facility (CEBAF)**, a unique international electron-beam user facility for the investigation of nuclear and nucleon structure based on the underlying quark substructure. The facility has a user community of ~1,200 researchers and is used annually by ~800 U.S. and foreign researchers. Polarized electron beams up to 5.7 GeV can be provided by CEBAF simultaneously to 3 different experimental halls. Hall A is designed for spectroscopy and few-body measurements. Hall B has a large acceptance detector, CLAS, for detecting multiple charged particles coming from a scattering reaction. Hall C is designed for flexibility to incorporate a wide variety of different experiments. Its core equipment consists of two medium resolution spectrometers for detecting high momentum or unstable particles. The G0 detector, a joint NSF-DOE project in Hall C, will allow a detailed mapping of the strange quark contribution to nucleon structure. Also in Hall C, a new detector, Q-weak, is being developed to measure the weak charge of the proton by a collaboration of laboratory and university groups in partnership with the NSF. TJNAF research and engineering staff are world experts in superconducting radio-frequency technology; their expertise is being used in the development of the 12 GeV Upgrade for CEBAF as well as for other accelerator projects such as the Spallation Neutron Source.

Science Laboratories Infrastructure

The SLI program enables Departmental research missions at the laboratory by funding line item construction and GPPs to maintain the general purpose infrastructure, the cleanup and removal of excess facilities, and the correction of health and safety deficiencies to ensure consistency with OSHA requirements.

Safeguards and Security

TJNAF has a guard force that provides 24-hour services for the accelerator site and after-hours property protection security for the entire site. Other security programs include cyber security, program management, and security systems.

Washington Headquarters

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

Basic Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Basic Energy Sciences					
Research					
Materials Sciences and Engineering	558,831	628,228	+6,904[ab]	635,132	746,143
Chemical Sciences, Geosciences, and Energy Biosciences	213,778	253,422	-13,947[ab]	239,475	221,801
Total, Research	772,609	881,650	-7,043	874,607	967,944
Construction	218,653	231,880	-1,855[a]	230,025	178,073
Total, Basic Energy Sciences	991,262[c]	1,113,530	-8,898	1,104,632	1,146,017

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act, 1977"
Public Law 103-62, "Government Performance and Results Act of 1993"

Mission

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

Benefits

BES delivers the knowledge needed to support the President's National Energy Plan for improving the quality of life for all Americans. In addition, BES works cooperatively with other agencies and the programs of the National Nuclear Security Administration to discover knowledge and develop tools to strengthen national security. As part of its mission, the BES program plans, constructs, and operates major scientific user facilities to serve researchers at universities, national laboratories, and industrial laboratories.

Basic research supported by the BES program touches virtually every aspect of energy resources, production, conversion, efficiency, and waste mitigation. Research in materials sciences and engineering leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety of energy generation, conversion, transmission, and use. For example, research on toughened

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[a] Includes a reduction of $8,898,000 for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005, as follows: Materials Sciences and Engineering ($-5,019,000); Chemical Science, Geosciences and Energy Biosciences ($-2,024,000); and Construction ($-1,855,000).
[b] Includes a reallocation of funding within BES in accordance with H. Rpt. 108-792, accompanying P.L. 108-447, as follows: Materials Sciences and Engineering ($+11,923,000) and Chemical Science, Geosciences and Energy Biosciences ($-11,923,000) to optimize funding for research and facility operations within the BES program.
[c] Includes reductions of $5,984,000 rescinded in accordance with P.L. 108-137, the Consolidated Appropriations Act, 2004, $17,258,000, which was transferred to the SBIR program, and $2,071,000, which was transferred to the STTR program.

ceramics will result in improved high-speed cutting tools, engine turbines, and a host of other applications requiring lightweight, high-temperature materials. Research in chemistry leads to the development of advances such as efficient combustion systems with reduced emissions of pollutants; new solar photo conversion processes; improved catalysts for the production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. Research in geosciences contributes to the solution of problems in multiple DOE mission areas, including reactive fluid flow studies to understand contaminant remediation and seismic imaging for reservoir definition. Finally, research in the molecular and biochemical nature of plant growth aids the development of renewable biomass resources and solar photoenergy conversion. History has taught us that seeking answers to fundamental questions results in a diverse array of practical applications as well as some remarkable revolutionary advances.

Strategic and Program Goals

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

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

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

Program Goal 5.22.00.00: Advance the Basic Science for Energy Independence – Provide the scientific knowledge and tools to achieve energy independence, securing U.S. leadership and essential breakthroughs in basic energy sciences.

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

Within the Basic Energy Sciences program, the Materials Science and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram contribute to Program Goal 5.22.00.00 by producing seminal advances in the core disciplines of the basic energy sciences – materials sciences and engineering, chemistry, geosciences, and energy biosciences. These subprograms build leading research programs that provide world-class, peer-reviewed research results cognizant of both DOE mission needs and new scientific opportunities. Scientific discoveries at the frontiers of these disciplines impact energy resources, production, conversion, efficiency, and the mitigation of the adverse impacts of energy production and use - discoveries that will accelerate progress toward energy independence, economic growth, and a sustainable environment.

Key scientific emphases of these subprograms will lead the coming revolutions in: science of the ultrasmall (the nanometer length scale); science of the ultrafast (the femtosecond time scale); and science of complex systems (systems whose properties cannot be described by the properties of their individual components, e.g., high-temperature superconductivity and coupled chemical reactions). Advances in these three areas will deliver the foundations and discoveries for a future built around controlled chemical processes and materials designed one atom at a time. Focus areas necessary to achieve this goal involve research programs of individual investigators and groups of investigators; the development of advanced tools and instruments for x-ray, neutron, and electron diffraction, scattering, and imaging; the development of other advanced probes of matter, e.g. using high electric or magnetic fields; and theory, modeling, and simulation using high-end computing. The following indicators establish specific long-term (10-year) goals in scientific advancement that the BES program is committed to and that progress can be measured against.

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

The Materials Science and Engineering subprogram also contributes to Program Goal 5.22.00.00 by managing BES facility operations and construction to the highest standards of overall performance, using merit evaluation with independent peer review. The synchrotron radiation light sources, neutron scattering facilities, and electron-beam microcharacterization centers reveal the atomic details of metals and alloys; glasses and ceramics; semiconductors and superconductors; polymers and biomaterials; proteins and enzymes; catalysts, sieves, and filters; and materials under extremes of temperature, pressure, strain, and stress. Researchers are now able to make new materials and study their atomic formation as it happens using these new probes. Once the province of specialists, mostly physicists, these facilities are now used by thousands of researchers annually from all disciplines. The Materials Science and Engineering subprogram is also establishing five Nanoscale Science Research Centers that will change the way materials research is done by providing the ability to fabricate complex structures using chemical, biological, and other synthesis techniques; characterize them; assemble them; and integrate them into devices—and do it all in one place. The Chemical Sciences, Geosciences, and Energy Biosciences subprogram contribute to this goal by managing the Combustion Research Facility at Sandia National Laboratories in Livermore, California, an internationally recognized facility for advanced characterization techniques and for the study of combustion science and technology.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 5.22.00.00 Advance the Basic Science for Energy Independence					
Materials Sciences and Engineering					
N/A	N/A	N/A	Improve Spatial Resolution: Spatial resolution for imaging in the hard x-ray region was measured at 100 nm and in the soft x-ray region was measured at 19 nm, and spatial information limit for an electron microscope of 0.078 nm was achieved. [Met Goal]	Improve Spatial Resolution: Demonstrate first measurement of spatial resolutions for imaging in the hard x-ray region of <100 nm and in the soft x-ray region of <18 nm, and spatial information limit for an electron microscope of 0.08 nm.	Improve Spatial Resolution: Demonstrate measurement of spatial resolutions for imaging in the hard x-ray region of <100 nm and in the soft x-ray region of <18 nm, and spatial information limit for an electron microscope of 0.08 nm.[a]
			Improve 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: Demonstrate first measurement of x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse ($>10^8$ photons/pulse).	Improve temporal resolution: Demonstrate measurement of x-ray pulses that are <100 femtoseconds in duration and have an intensity of >100 million photons per pulse ($>10^8$ photons/pulse).[a]
Chemical Sciences, Geosciences, and Energy Biosciences					
N/A	N/A	N/A	As a part of the Scientific Discovery through Advanced Computing (SciDAC) program, a two-dimensional combustion reacting flow simulation was performed involving 44 reacting species and 518,400 grid points. [Met Goal]	Improve Simulation: As a part of the SciDAC program, perform a three-dimensional combustion reacting flow simulation involving more than 10 reacting species and 0.2 billion grid points.	Improve Simulation: Perform a three-dimensional combustion reacting flow simulation involving more than 30 reacting species and 20 million grid points.
Materials Sciences and Engineering					
Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time. [Met Goal]	*Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time. [Met Goal]*	*Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time. [Met Goal]*	*Scientific user facilities were maintained and operated to achieve an average at least 90% of the total scheduled operating time (Results: 91.9%). [Met Goal]*	*Maintain and operate the scientific user facilities to achieve an average at least 90% of the total scheduled operating time.*	*Maintain and operate the scientific user facilities to achieve an average at least 90% of the total scheduled operating time.*

[a] No improvement is expected in FY 2006 as compared to the level of achievement for FY 2005. That is due to the performance levels for resolution (temporal and spatial) has reached the maximum for the current suite of available instruments. This target is a measure of SC's intent to maintain the maximum level of performance for users of the current SC facilities until the next generation of instruments and facilities become available.

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Construction					
Cost and timetables were maintained within 10% of the baselines given in the construction project data sheets for all construction projects ongoing during the year. [Met Goal]	*Cost and timetables were maintained within 10% of the baselines given in the construction project data sheets for all construction projects ongoing during the year. [Met Goal]*	*Cost and timetables were maintained within 10% of the baselines given in the construction project data sheets for all construction projects ongoing during the year. [Met Goal]*	*Cost and timetables were maintained within 10% of the baselines given in the construction project data sheets for all construction projects ongoing during the year (Results: +1.3% cost variance and +0.8% schedule variance). [Met Goal]*	*Meet the cost and timetables within 10% of the baselines given in the construction project data sheets for all ongoing construction projects.*	*Meet the cost and timetables within 10% of the baselines given in the construction project data sheets for all ongoing construction projects.*

Means and Strategies

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

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

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

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

Validation and Verification

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

Program Assessment Rating Tool (PART)

The Department implemented a tool to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government’s portfolio of programs. The structured framework of the PART provides a means by which programs can assess their activities differently than by traditional reviews. The BES program has incorporated feedback from OMB into the FY 2005 and FY 2006 Budget Request and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the BES program a very high score of 93% overall which corresponds to a rating of “Effective.” OMB found the program to be strategically driven and well managed. Outside expert panels have validated the program’s merit-based review processes ensuring that research supported is relevant and of very high quality. The assessment found that BES has developed a limited number of adequate performance measures which are continued for FY 2006. These measures have been incorporated into this Budget Request, BES grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain our scientific performance measures, the Office of Science developed a website (www.sc.doe.gov/measures.htm) that answers questions such as “What does this measure mean?” and “Why is it important?” Roadmaps, developed in consultation with the Basic Energy Sciences Advisory Committee (BESAC), will guide triennial reviews by BESAC of progress toward achieving the long term Performance Measures. These roadmaps are posted on the SC website. The Annual Performance Targets are tracked through the Department’s Joule system and reported in the Department’s Annual Performance Report.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 5.22.00.00 Advance the Basic Science for Energy Independence			
Materials Sciences and Engineering	558,831	635,132	746,143
Chemical Sciences, Geosciences and Energy Biosciences	213,778	239,475	221,801
Construction	218,653	230,025	178,073
Total, General Goal 5, World-Class Scientific Research Capacity	991,262	1,104,632	1,146,017

Overview

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

Today, the BES program is one of the Nation's largest sponsors of research in the natural sciences. It is uniquely responsible for supporting fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences impacting energy resources, production, conversion, and efficiency, and the mitigation of the adverse impacts of energy production and use. In FY 2004, the program funded research in more than 175 academic institutions located in 49 states and in 13 Department of Energy (DOE) laboratories located in 9 states. BES supports a large extramural research program, with approximately 35% of the program’s research activities sited at academic institutions.

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

The 2001 “National Energy Policy” noted that the U.S. economy grew by 126% since 1973, but energy use increased by only 30%. Approximately one-half to two-thirds of the savings resulted from technological improvements in products and services that allow consumers to enjoy more energy services without commensurate increases in energy demand. At the heart of these improvements is fundamental research. During this 30-year period, the basic research supported by the BES program has touched virtually every aspect of energy resources, production, conversion, efficiency, and waste mitigation. The basic knowledge derived from fundamental research has resulted in a vast array of advances, including:

- high-energy and high-power lithium and lithium ion batteries and thin-film rechargeable microbatteries;
- thermoacoustic refrigeration devices that cool without moving parts and without the use of freons;
- compound semiconductors, leading to the world's highest efficiency photovoltaic solar cells;
- catalysts for the production of new polymers (annually, a multibillion dollar industry) and for a host of other products and energy-efficient processes;
- high-strength, lightweight magnets for sensors and for small motors used in power steering and other vehicle functions;
- strong, ductile alloys for use in high-temperature applications;
- nonbrittle ceramics for use in hammers, high-speed cutting tools, engine turbines, and other applications requiring lightweight and/or high-temperature materials;
- new steels, improved aluminum alloys, magnet materials, and other alloys;
- polymer materials for rechargeable batteries, car bumpers, food wrappings, flat-panel displays, wear-resistant plastic parts, and polymer-coated particles in lubricating oils;
- processes for extraction of radioactive and hazardous metal ions from solutions for nuclear fuel purification/reprocessing and for cleanup of radioactive wastes; and
- a host of new instruments, e.g., instruments based on high-temperature superconductors that can sense the minute magnetic fields that emanate from the human brain and heart.

These advances came by exploiting the results of basic research that sought answers to the most fundamental questions in materials sciences, chemistry, and the other disciplines supported by BES.

The future holds even greater promise, largely because of our new atom-by-atom understanding of matter and the subsequent unprecedented ability to design and construct new materials with properties that are not found in nature. This understanding comes in large measure from synchrotron x-ray and neutron scattering sources, electron microscopes, and other atomic probes as well as terascale computers. The BES program has played a major role in enabling the nanoscale revolution. This impact results from a deliberate philosophy of identifying seminal challenges and establishing both facilities and coordinated programs that transcend what individuals alone can do. The program in nanoscale science, including the formation of Nanoscale Science Research Centers, continues that philosophy.

The new millennium will take us deep into this world of complex nanostructures. Here, simple structures interact to create new phenomena, and large complicated structures can be designed atom by atom for desired characteristics. We will design new tiny objects “from scratch” that have unprecedented optical, mechanical, electrical, or chemical properties that address the needs of human society.

How We Work

To ensure that the most scientifically promising research is supported, the BES program engages in long-range planning and prioritization; regular external, independent review of the supported research to ensure quality and relevance; and evaluation of program performance through establishment and subsequent measurement against goals and objectives. These activities rely heavily on input from external sources including workshops and meetings of the scientific community, advice from the federally chartered Basic Energy Sciences Advisory Committee (BESAC), Interagency Working Groups, and reports from other groups such as the National Academy of Sciences. To accomplish its mission, the BES program supports research in both universities and DOE laboratories; plans, constructs, and operates world-class scientific user facilities; and maintains a strong infrastructure to support research in areas of core competencies. Some of the details of how we work are given in the sections below.

Advisory and Consultative Activities

Charges are provided to BESAC by the Director of the Office of Science. During the past few years, BESAC has provided advice on new directions in nanoscale science and complex systems; on the operation of the major scientific user facilities; on the need for new, "next-generation" facilities for x-ray, neutron, and electron-beam scattering; on performance measurement; on the quality of the BES program management and its consequent impacts on the program portfolio; on new directions in research relating to specific aspects of fundamental science such as catalysis, biomolecular materials, and computational modeling at the nanoscale; on the fundamental research challenges posed by the Department's energy missions; on a 20-year roadmap for BES facilities; and on theory and computation needs across the entire portfolio of BES research. Of particular note is the BESAC report "Basic Research Needs to Assure a Secure Energy Future", which describes 10 themes and 37 specific research directions for increased emphasis. This report will help the program map its research activities for many years to come.

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

Facility Reviews

Facilities are reviewed using (1) external, independent review committees operating according to the procedures established for peer review of BES laboratory programs and facilities (http://www.science.doe.gov/bes/labreview.html) and (2) specially empanelled subcommittees of BESAC. During the past eight years, BESAC subcommittees have reviewed the synchrotron radiation light sources, the neutron scattering facilities, and the electron-beam microcharacterization facilities. The reports of these reviews are available on the BES website (http://www.science.doe.gov/bes/BESAC/reports.html). Regardless of whether a review is by an independent committee charged by a BES program manager or by a BESAC subcommittee charged by the Director of the Office of Science, the review has standard elements. Important aspects of the reviews include assessments of the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; user satisfaction; facility staffing levels; R&D activities to advance the facility; management of the facility; and long-range goals of the facility. These reviews have identified both best practices and substantive issues, including those associated with mature facilities. For example, the reviews clearly highlighted the change that occurred as the light sources transitioned from a mode in which they served primarily expert users to one in which they served very large numbers of inexperienced users in a wide variety of disciplines. The light sources experienced a quadrupling of the number of users in the decade of the 1990s. This success and its consequent growing pains were delineated by our reviews. The outcomes of these reviews helped develop new models of operation for existing light sources and neutron scattering facilities as well as the new Spallation Neutron Source now under construction. Facilities that are in design or construction are reviewed according to procedures set down in DOE Order 413.3 "Program and Project Management for Capital Assets" and in the Office of Science "Independent Review Handbook" (http://www.science.doe.gov/SC-80/sc-81/docs.html#DOE). In general, once a project has entered the construction phase (e.g., the Spallation Neutron Source, the Linac Coherent Light Source, or the Nanoscale Science Research Centers), it is reviewed with external, independent committees approximately biannually. These Office of Science construction project reviews enlist experts in the technical scope of the facility under construction and its costing, scheduling, and construction management.

Program Reviews

All research projects supported by the BES program undergo regular peer review and merit evaluation based on procedures set down in 10 CFR Part 605 for the extramural grant program and in an analogous process for the laboratory programs (http://www.science.doe.gov/bes/labreview.html). These peer review and merit evaluation procedures are described within documents found at http://www.science.doe.gov/bes/peerreview.html. These evaluations assess:

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

In addition, on a rotating schedule, BESAC reviews the major elements of the BES program using Committees of Visitors (COVs). COVs are charged with assessing the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document proposal actions; the quality of the resulting portfolio, specifically the breadth and depth of portfolio elements and the national and international standing of the elements; and progress toward the long-term PART goals. The first three reviews assessed the chemistry activities (FY 2002), the materials sciences and engineering activities (FY 2003), and the activities associated with the management of the light sources, the neutron sources, and the new Nanoscale Science Research Centers (2004). This COV review cycle will begin again in FY 2005, so that all elements of the BES program are reviewed every three years.

Planning and Priority Setting

Because the BES program supports research covering a wide range of scientific disciplines as well as a large number of major scientific user facilities, planning is an ongoing activity. Many long-range planning exercises for elements of the BES program are performed under the auspices of BESAC. Prioritization within each of these program elements is achieved via such studies. Prioritization across the entirety of the BES program is more complex than that for a homogeneous program where a single planning exercise results in a prioritization.

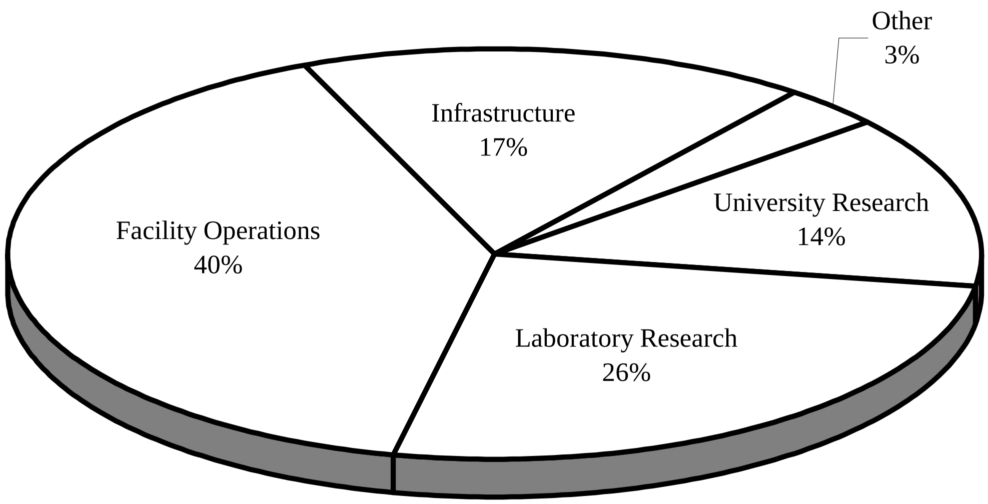
Inputs to our prioritization include overall scientific opportunity, projected investment opportunity, DOE mission need, and Administration and Departmental priorities. During the past few years, these considerations have led to: increased investments in science at the nanoscale to take advantage of the remarkable knowledge gained from atomic-scale understanding of materials; increased investments for operations of the major user facilities in recognition of the quadrupling of users in the past decade and to reap the rewards of the capital investments in the facilities themselves; increased investments for instrumentation at the facilities so that the quality of the instruments will match the world-class quality of the facilities; increased investments for ultrafast science to probe processes that happen on the timescale of chemical reactions; and increases for targeted program areas for which both scientific opportunity and mission need are high (e.g., catalysis) or for which BES represents the sole U.S. steward of the field (e.g., heavy-element chemistry). Construction of new user facilities such as the Spallation Neutron Source, the Linac Coherent Light Source, the Nanoscale Science Research Centers, or upgrades to existing facilities such as the High Flux Isotope Reactor or the Stanford Synchrotron Radiation Laboratory follow from input from BESAC and National Academy of Sciences studies and from broad, national strategies that include the input from multiple federal agencies.

The FY 2006 budget request continues priorities established in the past few years. Construction of the Spallation Neutron Source will be completed in accord with the established baseline. A significant investment in the area of nanoscale science includes construction and operations funding for four new Nanoscale Science Research Centers at Oak Ridge National Laboratory, Lawrence Berkeley National Laboratory, the combination of Sandia National Laboratories and Los Alamos National Laboratory, and Brookhaven National Laboratory. Finally, continued support for a Major Item of Equipment (MIE) is requested for the fifth and final Nanoscale Science Research Center at Argonne National Laboratory. That Center is being built in partnership with the State of Illinois, which provided $36,000,000 in FY 2003 and FY 2004 for the construction of the building. BES funding will provide clean rooms, instrumentation, and ultimately operations support for the Center. Project Engineering Design and Construction funding also are provided for the Linac Coherent Light Source (LCLS), a 4th generation light source that will provide orders of magnitude higher intensities of x-ray light than do current synchrotron radiation light sources. The LCLS will be a facility for groundbreaking research in the physical and life sciences owing to its femtosecond pulses of extremely high peak brightness x-ray beams. It will be the first such facility in the world.

How We Spend Our Budget

The BES program has three major program elements: research, facility operations, and construction and laboratory infrastructure support. Approximately 35% of the research funding goes to support work in universities with most of the remainder going to support work in DOE laboratories. The facility operations budget has grown relative to the research budget over the past decade, reflecting the commissioning of new and upgraded facilities as well as the increased importance of these facilities in enabling the research of thousands of researchers across the Nation. Project Engineering Design (PED) and construction remain significant budget components in FY 2006, including the Spallation Neutron Source, the Nanoscale Science Research Centers, and the Linac Coherent Light Source.

Basic Energy Sciences Budget Allocation FY 2006



Research

The BES program is one of the Nation's largest supporters of fundamental research in materials sciences, chemistry, geosciences, and aspects of biosciences. Research is supported in both DOE laboratories and universities. While peer review of all research ensures outstanding quality and relevance, each of the two research sectors has unique characteristics and strengths.

National Laboratory Research: Research sited at DOE laboratories often takes advantage of the premier scientific user facilities for x-ray, neutron, and electron beam scattering at the laboratories as well as other specialized facilities, such as hot cells, that are not typically found at universities. Mission critical research is also sited at DOE laboratories when it is outside of the mainstream of research supported at universities, e.g., heavy-element chemistry or combustion chemistry. Research sited at DOE laboratories is very often collocated with and sometimes cofunded with research activities of the DOE technology offices, providing a synergism not available in universities. Finally, research that requires strong interdisciplinary interactions, large teams of closely collaborating researchers, or a large technical support staff is also well suited to DOE laboratories.

University Research: Universities provide access to the Nation's largest scientific talent pool and to the next-generation of scientists. Development of the workforce through the support of faculty, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills is a high priority. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. Furthermore, engaging faculty and students in the work of the BES program develops a broad appreciation for the basic research needs associated with the program.

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

Significant Program Shifts

In FY 2006, there are a number of significant program milestones and increases, including the following:

- Construction of the Spallation Neutron Source will be completed, and the facility will begin operation at the planned funding level.
- All five Nanoscale Science Research Centers are nearing completion; four of them will begin operation in FY 2006. The Center for Nanophase Materials Sciences at Oak Ridge National Laboratory, the Molecular Foundry at Lawrence Berkeley National Laboratory, and the Center for Integrated Nanotechnologies at Sandia National Laboratories and Los Alamos National Laboratory all will begin operation at the planned funding levels. In addition, the Center for Nanoscale Materials at Argonne National Laboratory will begin limited operation following the completion of its building (funded by the State of Illinois) and prior to the completion of the BES-funded Major Item of Equipment, which provides the instrumentation for that Center.
- The Linac Coherent Light Source will continue Project Engineering Design (PED) and will begin construction at the planned levels. Funding is provided separately for preconceptual design of instruments for the facility. Funding is also provided to partially support operation of the SLAC linac. This marks the beginning of the transition to LCLS operations at SLAC.
- The Transmission Electron Aberration Corrected Microscope project is initiated as a Major Item of Equipment.
- Research to realize the potential of a hydrogen economy will be increased from $29,183,000 to $32,500,000. The research program is based on the BES workshop report "Basic Research Needs for the Hydrogen Economy."

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

In order to accomplish these very high-priority, forefront activities, some difficult choices had to be made. In particular, the BES support for the Radiochemical Engineering and Development Center at Oak Ridge National Laboratory is terminated. The operations budgets of the remaining facilities are funded at about the same level as in FY 2005, which will decrease the available beam time and service to users. Finally, research activities are funded at a level approximately 3% less than in FY 2005; while no research activities are terminated, there are reductions throughout.

Nanoscience and Nanoscale Science Research Centers *(*NSRCs) are user facilities for the synthesis, processing, fabrication, and analysis of materials at the nanoscale. They are designed to enable the nanoscale revolution by collocating multiple research disciplines, multiple techniques, and a wide variety of state-of-the-art instrumentation in a single building. The NSRCs are designed to promote rapid advances in the various areas of nanoscale science and technology.

NSRCs are sited adjacent to or near an existing BES synchrotron or neutron scattering facility to enable rapid characterization of newly fabricated materials. Contained within NSRCs will be clean rooms; chemistry, physics, and biology laboratories for nanofabrication; and one-of-a-kind signature instruments and other instruments, e.g., nanowriters and various research-grade probe microscopies, not generally available outside of major user facilities. NSRCs will serve the Nation's researchers broadly and, as with the existing BES facilities, access to NSRCs will be through submission of proposals that will be reviewed by mechanisms established by the facilities themselves.

NSRCs were conceived in FY 1999 within the context of the NSTC Interagency Working Group on Nanoscale Science, Engineering, and Technology as part of the DOE contribution to the National Nanotechnology Initiative. Planning for the NSRCs has included substantial participation by the research community through a series of widely advertised and heavily attended workshops attracting a total of about 2,000 researchers.

As was described in the recent National Research Council report “Small Wonders, Endless Frontiers – A Review of the National Nanotechnology Initiative,” new processes that couple top-down and bottom-up assembly techniques “will allow the fabrication of highly integrated two- and three-dimensional devices and structures to form diverse molecular and nanoscale components. They would allow many of the new and promising nanostructures, such as carbon nanotubes, organic molecular electronic components, and quantum dots, to be rapidly assembled into more complex circuitry to form useful logic and memory devices. Such new devices would have computational performance characteristics and data storage capacities many orders of magnitude higher than present devices and would come in even smaller packages. Nanomaterials and their performance properties will also continue to improve. Thus, even better and cheaper nanopowders, nanoparticles, and nanocomposites should be available for more widespread applications. Another important application for future nanomaterials will be as highly selective and efficient catalysts for chemical and energy conversion processes. This will be important economically not only for energy and chemical production but also for conservation and environmental applications. Thus, nanomaterial-based catalysis may play an important role in photoconversion devices, fuel cell devices, bioconversion (energy) and bioprocessing (food and agriculture) systems, and waste and pollution control systems.”

The following table summarizes the BES investments in research at the nanoscale.

Nanoscale Science Research Funding

(dollars in thousands)

	TEC	TPC	FY 2004	FY 2005	FY 2006
Research					
Materials Sciences and Engineering			73,501	66,995	112,632
Chemical Sciences, Geosciences, and Biosciences			27,833	28,360	26,914
Capital Equipment					
Major Item of Equipment — ANL, Center for Nanoscale Materials			10,000	12,000	14,000
Nanoscale Science Research Centers					
PED – All sites			2,982	1,996	0
Construction					
BNL, Center for Functional Nanomaterials	79,700	81,000	0	18,317	36,553
LBNL, Molecular Foundry	83,700	85,000	34,794	31,828	9,606
ORNL, Center for Nanophase Materials Sciences	63,740	64,740	19,882	17,669	0
SNL/A and LANL, Center for Integrated Nanotechnologies	73,800	75,800	29,674	30,650	4,626
Total, BES Nanoscale Science Funding			198,666	207,815	204,331

Basic Research in Support of the Hydrogen Economy. In FY 2006, $32,500,000 is requested for activities to realize the potential of a hydrogen economy. The research program is based on the BES workshop report “Basic Research Needs for the Hydrogen Economy” that can be found at http://www.science.doe.gov/production/bes/hydrogen.pdf. The 2003 report highlights the enormous gap between our present capabilities for hydrogen production, storage, and use and those required for a competitive hydrogen economy. To be economically competitive with the present fossil fuel economy, the cost of fuel cells must be lowered by a factor of five and the cost of producing hydrogen must be lowered by a factor of four. Moreover, the performance and reliability of hydrogen technology for transportation and other uses must be improved dramatically. Simple incremental advances in the present state-of-the-art cannot bridge this gap. Narrowing the gap significantly will require a comprehensive, long-range program of innovative high-risk/high-payoff basic research that is intimately coupled to and coordinated with applied programs. The objective of such a program must not be evolutionary advances but revolutionary breakthroughs in understanding and in controlling the chemical and physical interactions of hydrogen with materials. Detailed findings and research directions identified by the three panels are presented in the report.

In response to the BES solicitation on Basic Research for the Hydrogen Fuel Initiative for FY 2005 funding, 668 qualified preapplications were received in five submission categories: (1) novel materials for hydrogen storage, (2) membranes for separation, purification, and ion transport, (3) design of catalysts at the nanoscale, (4) solar hydrogen production, and (5) bio-inspired materials and processes. A total of $21,473,000 in new funding will be awarded as a result of this solicitation. Three of the five focus areas – novel storage materials, membranes, and design of catalysts at the nanoscale – accounted for about 75% of the submissions. Following a review, principal investigators on about 40% of the preapplications were invited to submit full applications, which will be peer reviewed according to the guidelines in 10 CFR 605. Awards will be made in late FY 2005. BES involved staff from EERE in the preapplication review process to ensure basic research relevance to technology program goals. Furthermore, BES will participate in EERE's annual program review meeting to promote information sharing and, beginning in FY 2006, will organize parallel sessions at that meeting for the BES principal investigators.

President's Hydrogen Initiative

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Materials Sciences and Engineering Research	3,055	14,761	16,600
Chemical Sciences, Geosciences, and Biosciences	4,655	14,422	15,900
Total Hydrogen Initiative	7,710	29,183	32,500

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all Office of Science mission areas with the goal of achieving breakthrough scientific advances via computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit terascale computing and networking resources. The program is bringing computation and simulation to parity with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate modeling and prediction, plasma physics, particle physics, accelerator design, astrophysics, chemically reacting flows, and computational nanoscience.

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

Scientific Facilities Utilization

The BES program request supports the scientific user facilities. Research communities that have benefited from these facilities include materials sciences, condensed matter physics, chemical sciences, earth and geosciences, environmental sciences, structural biology, superconductor technology, medical research, and industrial technology development. The funding level for operation of the light sources, the Intense Pulse Neutron Source, and the High-Flux Isotope Reactor will be approximately equal to that in FY 2005; without cost of living increases, the level of operations will be about ten percent less than that in FY 2005. The reduction in funding from FY 2005 to FY 2006 for some of these facilities is a result of one-time increases in FY 2005 for capital equipment or other special needs such as fuel and maintenance at the High Flux Isotope Reactor. More detailed descriptions of the specific facilities and their funding are given in the subprogram narratives and in the sections entitled Site Description and Major User Facilities.

Two tables follow: The first shows the hours of operation and numbers of users for the major scientific user facilities – the synchrotron radiation sources and the neutron scattering facilities. The second shows cost and schedule variance. Note: Cost Variance is the difference between the value of the physical work performed and the actual cost expended. A negative result is unfavorable and indicates the potential for a cost overrun. Schedule variance is the difference between the value of the physical work performed and the value of the work planned. A negative result is unfavorable and indicates that the project is behind schedule. Variance data are shown as percents. They are shown against the project's performance measurement baseline that includes cost and schedule contingency and are as of the end of each fiscal year. All projects have met or are on schedule to meet all Level 0 and Level 1 Milestones, which are shown in the table.

Synchrotron Light Source and Neutron Scattering Facility Operations

	FY 2004 Actual[a]	FY 2005 Estimate	FY 2006 Estimate
All Facilities			
Optimal Hours[b]	36,800	29,800	32,200
Scheduled Hours	28,004	29,800	28,800
Unscheduled Downtime	8%	<10%	<10%
Number of Users	8,545	8,680	7,850
Advanced Light Source			
Optimal Hours[b]	5,700	5,600	5,600
Scheduled Hours	5,162	5,600	5,100
Unscheduled Downtime	4%	<10%	<10%
Number of Users	1,898	1,900	1,700
Advanced Photon Source			
Optimal Hours[b]	5,700	5,000	5,000
Scheduled Hours	5,113	5,000	4,500
Unscheduled Downtime	2%	<10%	<10%
Number of Users	2,773	2,800	2,500
National Synchrotron Light Source			
Optimal Hours[b]	5,700	5,500	5,500
Scheduled Hours	5,287	5,500	5,000
Unscheduled Downtime	4%	<10%	<10%
Number of Users	2,299	2,300	2,100
Stanford Synchrotron Radiation Laboratory			
Optimal Hours[b]	5,300	3,700	5,000
Scheduled Hours	2,651	3,700	4,200
Unscheduled Downtime	3%	<10%	<10%
Number of Users	741	800	800
High Flux Isotope Reactor			
Optimal Hours[b]	6,100	3,300	4,400
Scheduled Hours	3,096	3,300	4,000
Unscheduled Downtime	29%	<10%	<10%
Number of Users	48	100	100

[a] Scheduled hours for FY 2004 show actual number of hours delivered to users.
[b] Optimal hours for FY 2005 and FY 2006 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. This constitutes a definitional change from previous years. The figures for FY 2004 reflect the theoretical maximum number of hours the facilities could operate annually under ideal circumstances and maximum funding.

	FY 2004 Actual[a]	FY 2005 Estimate	FY 2006 Estimate
Intense Pulsed Neutron Source			
Optimal Hours[b]	4,700	3,600	3,600
Scheduled Hours	4,052	3,600	3,200
Unscheduled Downtime	0%	<10%	<10%
Number of Users	279	280	250
Manuel Lujan, Jr. Neutron Scattering Center			
Optimal Hours[b]	3,600	3,100	3,100
Scheduled Hours	2,643	3,100	2,800
Unscheduled Downtime	19%	<10%	<10%
Number of Users	507	500	400

Cost and Schedule Variance

	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate
Spallation Neutron Source			
Cost Variance	+0.3%		
Schedule Variance	-1.25		
Major (Levels 0 and 1) Milestones Completed or Committed to	None	Instrument Systems Design Complete	Ring Beam Available to Target
		Linac Beam Available to Ring	Approve Critical Decision 4 – Start of Operations
Linac Coherent Light Source (SLAC)			
Cost Variance	0%		
Schedule Variance	0%		
Major (Levels 0 and 1) Milestones Completed or Committed to		Approve Critical Decision 2b – Performance Baseline	Approve Critical Decision 3b – Start Construction
		Approve Critical Decision 3a – Start Long-Lead Procurement	

[a] Scheduled hours for FY 2004 show actual number of hours delivered to users.
[b] Optimal hours for FY 2005 and FY 2006 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. This constitutes a definitional change from previous years. The figures for FY 2004 reflect the theoretical maximum number of hours the facilities could operate annually under ideal circumstances and maximum funding.

	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate
Center for Nanophase Materials Sciences (ORNL)			
Cost Variance	+.03%		
Schedule Variance	-.03%		
Major (Levels 0 and 1) Milestones Completed or Committed to		Approve Critical Decision 4a – Start Initial Operations	Approve Critical Decision 4b – Start Full Operations
Center for Integrated Nanotechnologies (SNL/LANL)			
Cost Variance	+0.4%		
Schedule Variance	-0.1%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 3a – Start Utility Construction Approved Critical Decision 3b – Start of Full Construction	None	Approve Critical Decision 4a – Start Initial Operations
The Molecular Foundry (LBNL)			
Cost Variance	-0.1%		
Schedule Variance	-0.1%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 3 – Start Construction	None	Approve Critical Decision 4a – Start of Initial Operations
Center for Nanoscale Materials (ANL)			
Cost Variance	+4.3%		
Schedule Variance	-10.1%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approved Critical Decision 2 – Performance Baseline Approve Critical Decision 3 – Start Construction	None	Approve Critical Decision 4a – Start of Initial Operations
Center for Functional Nanomaterials (BNL)			
Cost Variance	+0.8%		
Schedule Variance	-0.5%		
Major (Levels 0 and 1) Milestones Completed or Committed to	Approve Critical Decision 2 – Performance Baseline	Approve Critical Decision 3 – Start Construction	

	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate
SSRL SPEAR3 Upgrade			
Cost Variance	0%	N/A	N/A
Schedule Variance	0%	N/A	N/A
Major (Levels 0 and 1) Milestones Completed or Committed to	Complete Accelerator Readiness Review Start Commissioning Approve Critical Decision 4 – Start Operations	None	None

Construction and Infrastructure

Spallation Neutron Source (SNS) Project

The purpose of the SNS Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering. The SNS will be used by researchers from academia, national and federal labs, and industry for basic and applied research and for technology development in the fields of condensed matter physics, materials sciences, magnetic materials, polymers and complex fluids, chemistry, biology, earth sciences, and engineering. When completed in 2006, the SNS will be significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence – ISIS at the Rutherford Laboratory in England. The facility will be used by 1,000-2,000 scientists and engineers annually. Interest in the scientific community in the SNS is increasing.

Neutron scattering will play a role in all forms of materials research and design, including the development of smaller and faster electronic devices; lightweight alloys, plastics, and polymers for transportation and other applications; magnetic materials for more efficient motors and for improved magnetic storage capacity; and new drugs for medical care. The high neutron flux (i.e., high neutron intensity) from the SNS will enable broad classes of experiments that cannot be done with today's low-flux sources. For example, high flux enables studies of small samples, complex molecules and structures, time-dependent phenomena, and very weak interactions.

FY 2006 budget authority is requested to complete the SNS Project. Procurement and installation of equipment for instrument systems will be performed. An accelerator readiness review will be completed and target systems will be commissioned. All requirements to begin operations will be met and all SNS facilities will be turned over to operations.

The estimated Total Project Cost remains constant at $1,411,700,000. Additional information on the SNS Project is provided in the SNS construction project data sheet, project number 99-E-334.

Linac Coherent Light Source (LCLS) Project

Most x-ray experiments performed at synchrotron radiation light sources produce static pictures of materials averaged over relatively long times. However, the electrons and atoms in molecules, crystal lattices, polymers, biomaterials, and all other materials are in constant motion. Merely measuring atomic “form” will not tell us all there is to know about molecular “function.” We need to perform experiments that provide us with information on the motions of electrons and atoms in materials as well as their equilibrium positions. This will give us insight as never before possible into catalysis, chemical processes, protein folding, and molecular assembly.

The purpose of the LCLS Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak power and peak brightness than any existing coherent x-ray light source and that has pulse lengths measured in femtoseconds – the timescale of electronic and atomic motions. The advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons have revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be even more dramatic.

The LCLS Project will provide the world's first demonstration of an x-ray free-electron-laser (FEL) in the 1.5 - 15 Å range. The characteristics of the light from the LCLS will open new realms of scientific inquiry and applications in the chemical, material, and biological sciences including fundamental studies of the interaction of intense x-ray pulses with simple atomic systems, structural studies on single nanoscale particles and biomolecules, ultrafast dynamics in chemistry and solid-state physics, studies of nanoscale structure and dynamics in condensed matter, and use of the LCLS to create plasmas.

The LCLS project leverages capital investments in the existing SLAC linac as well as technologies developed for linear colliders and for the production of intense electron beams with radio-frequency photocathode guns. The SLAC linac will provide high-current, low-emittance 5–15 GeV electron bunches at a 120 Hz repetition rate. When traveling through a newly constructed long undulator, the electron bunches will lead to self-amplification of the emitted x-ray radiation, constituting the x-ray FEL. Optical devices beyond the undulator manipulate the direction, size, energy, and duration of the x-ray beam and carry it to whatever experiment is under way. The availability of the SLAC linac for the LCLS Project creates a unique opportunity (worldwide) for demonstration and use of x-ray FEL radiation. Most other free-electron lasers store the light from many passes of the electron beam through the undulator in an optical cavity before putting it to use. The LCLS will require just a single pass by the electron beam through the undulator, thanks largely to the low emittance of the electron beam at the front end of the system.

FY 2006 budget authority is requested to initiate physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Central Lab Office (CLO) Complex.

The estimated Total Project Cost is $379,000,000. Additional information on the LCLS Project is provided in the LCLS construction project data sheet, project number 05-R-320.

Nanoscale Science Research Centers (NSRCs)

Funds are requested for construction of NSRCs located at Lawrence Berkeley National Laboratory, at Sandia National Laboratories/Los Alamos National Laboratory, and at Brookhaven National Laboratory. Funds are also requested to continue the Major Item of Equipment for an NSRC at Argonne National Laboratory. Additional information on the NSRCs is provided in the Construction Project data sheets, project numbers, 03-R-313, 04-R-313, and 05-R-321 and in the Materials Sciences and Engineering subprogram.

General Plant Project (GPP) and General Plant Equipment (GPE)

BES provides funding for GPP and GPE for Argonne National Laboratory, Ames Laboratory, and Oak Ridge National Laboratory.

Workforce Development

The BES program supports development of the R&D workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. In addition, the BES scientific user facilities provide outstanding hands-on research experience to many young scientists. Thousands of students and post-doctoral investigators are among the 8,500 researchers who conduct experiments at BES-supported facilities each year. The work that these young investigators perform at BES facilities is supported by a wide variety of sponsors including BES, other Departmental research programs, other federal agencies, and private institutions. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research and also provides talent for a wide variety of technical and industrial areas that require the problem solving abilities, computing skills, and technical skills developed through an education and experience in fundamental research.

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	1,100	1,350	1,200
Average Size	$145,000	$150,000	$150,000
# Permanent Ph.D.s (FTEs)	3,650	4,240	3,940
# Postdoctoral Associates (FTEs)	1,050	1,220	1,140
# Graduate Students (FTEs)	1,690	1,960	1,820

Materials Sciences and Engineering

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Materials Sciences and Engineering					
Materials Sciences and Engineering Research	260,693	294,367	270,742	-23,625	-8.0%
Facilities Operations	298,138	325,242	457,069	+131,827	+40.5%
SBIR/STTR	0	15,523	18,332	+2,809	+18.1%
Total, Materials Sciences and Engineering	558,831	635,132	746,143	+111,011	+17.5%

Description

This subprogram extends the frontiers of materials sciences and engineering to expand the scientific foundations for the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and use. The subprogram also plans, constructs, and operates the major x-ray scattering and neutron scattering scientific user facilities and the Nanoscale Science Research Centers.

Benefits

Ultimately the research leads to the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and use. For example, the fuel economy in automobiles is directly proportional to the weight of the automobile, and fundamental research on strength of materials has led to stronger, lighter materials, which directly affects fuel economy. The efficiency of a combustion engine is limited by the temperature and strength of materials, and fundamental research on alloys and ceramics has led to the development of materials that retain their strength at high temperatures. Research in semiconductor physics has led to substantial increases in the efficiency of photovoltaic materials for solar energy conversion. Fundamental research in condensed matter physics and ceramics has underpinned the development of practical high-temperature superconducting wires for more efficient transmission of electric power.

Supporting Information

The subprogram supports basic research to understand the atomistic basis of materials properties and behavior and how to make materials perform better at acceptable cost through new methods of synthesis and processing. Basic research is supported in magnetic materials, semiconductors, superconductors, metals, ceramics, alloys, polymers, metallic glasses, ceramic matrix composites, catalytic materials, surface science, corrosion, neutron and x-ray scattering, chemical and physical properties, welding and joining, non-destructive evaluation, electron beam microcharacterization, nanotechnology and microsystems, fluid dynamics and heat transfer in materials, nonlinear systems, and new instrumentation.

This subprogram, a premier sponsor of condensed matter and materials physics in the U.S., is the primary supporter of the BES user facilities, and is responsible for the construction of the Spallation Neutron Source, the five Nanoscale Science Research Centers, and the Linac Coherent Light Source.

Selected FY 2004 Research Accomplishments

- The Ultimate Analysis: Single-Atom Spectroscopy in Bulk Solids. A longstanding dream in materials sciences and engineering has been to see and study those specific individual atoms that are critical to bulk properties and to determine their location and active configuration. Now, through an enhanced scanning transmission electron microscope with improved optics, researchers are able to observe an individual atom within its bulk environment and characterize its chemical state via spectroscopic means, determining its valence and bonding with nearest neighbors. The advance was made possible by correction of lens aberrations in the electron microscope to give a smaller yet brighter beam with a diameter of approximately 1 Ångstrom. Single-atom sensitivity, the ultimate analysis, opens up all areas of materials science and engineering to fundamental investigations in a revolutionary way.
- New Thin-film Texture Discovered with Potential for Nanotech Applications. One of the most fundamental structural properties of a thin film is its "texture," which is the orientation of individual grains with respect to the deposition substrate. Three types of texture are commonly observed: random, where no single orientation is dominant; fiber-texture, where the film grains are parallel to the growth direction, but random about that direction; and epitaxial, where the film orientation is fixed in three dimensions with respect to the substrate. The new, fourth type of texture, named axiotaxy, was observed in a number of thin film systems in which the film and substrate share a common plane orientation as a consequence of crystal lattice matching. This new texture provides a potential method for assembling large numbers of nanocrystals in regular patterns for nanotech applications.
- Negative Refraction - New Frontier for Superlenses. The first demonstration of negative and positive refraction of visible light at the same crystal interface was recognized as one of the "Top 15 Physics News Stories of 2003" by the American Institute of Physics. Nature provides us with optical refraction which is always positive: that is, the incident and transmitted light through an interface of two different media are on opposite sides of the interface normal. For negative refraction, they are on the same side of the interface normal. The beauty of negative refraction is total transmission and zero reflection, regardless of the angle of light incidence. These properties lend themselves to the creation of "super lenses." Laser beams can be steered in nano-photonic devices without loss, and optical telescopes can be built with higher resolution. The new interface uses a ferroelastic twin domain boundary such as a yttrium vanadate (YVO_4) bi-crystal and is applicable to any frequency of the electromagnetic spectrum. As a vision for the future, electron beams could be focused more efficiently in highly sensitive electron microscopes.
- Multi-band Semiconductors for High Efficiency Solar Cells. A new semiconductor material has been discovered that has multiple energy gaps, instead of the usual one, allowing for ultra-efficient energy capture of sunlight. Multi-band semiconductors were theoretically predicted over 20 years ago, but only now through the properties of so-called "highly mismatched alloys" (HMAs) have they been achieved. HMAs are compound semiconductors in which a small fraction of the anions are replaced with more electronegative atoms, producing a material with a new band having a strong quantum mechanical interaction with either the occupied valence band or the empty conduction band of the host semiconductor. Using this approach it was predicted, and subsequently demonstrated experimentally, that a II-VI semiconductor compound (ZnMnTe) with a small fraction (~1%) of the group VI constituent, i.e., tellurium, replaced by oxygen operates as a multiband semiconductor. Theoretical evaluation indicates that a single junction solar cell fabricated from this material could achieve a power conversion efficiency of 56%.

- Individual Carbon Nanotubes as Nanoscale Light Sources. A single carbon nanotube with a diameter of only 1.4 nanometer was used to fabricate the smallest source of light that can be controlled by electric current. The emission spectrum (color) of the light varied as a function of nanotube length and diameter. The center of the spectrum is determined by the nanotube diameter while the width of the spectrum depends on the length of the nanotube. Long nanotubes (50,000 nanometers) had narrow, symmetric emission spectra (characteristic of cold electrons) centered at the bandgap of the nanotube, which is inversely proportional to the nanotube diameter. Short nanotubes (500 nanometers) were also peaked at the bandgap of the nanotube, but showed broad, asymmetric spectra with a tail on the high-energy side, characteristic of hot electrons. These spectra show the cooling of hot electrons in nanotubes as a function of length through excitation of vibrations of the nanotube. The demonstrated understanding and control of optical properties using nanotubes could be important for optoelectronic nanotechnology.
- Magnetic Resonance Imaging at the Nanoscale. An innovative magnetic resonance approach to characterizing nano-porosity in a variety of materials has been developed. Magnetic resonance imaging (MRI) has been tremendously successful in visualizing resident deformities and the presence of disease in soft, porous biological tissues of the liver or kidney, yet the limited resolution precludes characterization at the nanometer scale. By using a technique of percolating inert gas through a nanoporous structure and then determining both the "sticking coefficient" of the gas and the time it takes for the gas to move away from the pore structure, MRI can now evaluate both the pore size distribution and the nature of the pore connectivity. This allows the analysis of highly porous structures that are present in many living systems and those created artificially in the laboratory such as filters to sequester pollutants, catalysts for chemical reactions, highly efficient insulators, and high strength to weight ratio materials for structural applications. By understanding the relationship between processing parameters and porosity of the resultant materials, advances in porous materials can be made.
- Nano-Trains: Nanoparticle Transport Using Motor Proteins. An active transport system that can be used to pick up, transport, and deposit nanoparticles within a microfluidic system has been developed. The active transport system is powered by the motor protein kinesin, a naturally occurring molecular machine. In the presence of a fuel source (adenosine triphosphate, or ATP), the head groups in the motor proteins “walk” rapidly along protein fibers called microtubules. With the tails of kinesin fixed to a surface the proteins can be used to propel the microtubules across the surface. The microtubules can now be modified to carry various size particles, ranging from 10 micrometers to 10 nanometers, and in large quantities, by functionalizing segments of the microtubules to carry cargo, like train “cars,” while leaving other segments unfunctionalized to act as “engines” by allowing free interaction with the motor proteins. This discovery suggests that highly non-equilibrium structures could be developed using the same active transport strategies that organisms employ for tissue assembly and muscle actuation.
- How Do Complex Fluids Jam? Is the mechanism for flow jamming the same for solid particulate matter (such as powders, coal, grain, pills, etc.) as for foam (bubbles in a fluid)? Two processes that rely on flowing foam are oil extraction and mineral separation. A major feature of both is that the flow can spontaneously stop, or jam, as the bubbles block each other. A better understanding of the causes of jamming will improve processes relying on flow. Recent studies using model foam systems have measured the coexistence between a flowing phase and a jammed phase. A surprising result was that this behavior was different from jamming observed in solid particulate systems. It

provided evidence for at least two different mechanisms of jamming, a critical step in furthering the understanding of the jamming process.

- Electron Transport in Semiconductor Quantum Wires. Spintronics (electronic phenomena that depend on electron spins) may provide a route to future generations of high-speed, low-power, nanoelectronics and may open up new areas of technology such as solid-state-based quantum computing. Significant challenges exist to realize these goals, including how to detect – or read – the electron spin in an electrical measurement. It has recently been demonstrated how such detection can be achieved in practice by exploiting the unique features of electron transport in semiconductor nanostructures known as quantum wires. Experiments show that the spin state of one quantum wire can be detected by studying the conductance of another wire located in close proximity. Theoretical work supports the idea that these experiments provide non-local detection of the electron spin opening pursuit of applications of this work to solid-state approaches to quantum computing.
- Superfluid Excitons at High Magnetic Field. A grand challenge for condensed matter physics is the observation of a new phase of matter created by the "condensation" of excitons, which are electron-hole pairs. Because excitons are bosons, any number can occupy a single quantum state. Thus, at low temperature, they should condense into the lowest energy level. Unfortunately, observation of this has been hindered by the rapid recombination of the electron and hole. Using magnetic fields to create stable exciton gases in doped double-layer semiconductor structures, the first evidence for condensation of an exciton gas was found in quantum tunneling measurements. The signature of the condensation was that both the conventional and Hall resistances of the sample become extremely small at low temperature. This nascent superfluidity is the strongest evidence yet for excitonic Bose condensation.
- Going from Good to Great: Doubling the Superconducting Upper Critical Field of Magnesium Diboride. In January 2001, a simple compound, magnesium diboride (MgB_2) was discovered to superconduct at a remarkably high temperature of 40 K, double the 20 K value for the niobium-based industrial standard. However, in its pure form, the material stops superconducting in a low magnetic field. During the past year, it was determined that the material continues to be superconducting in high fields if a small amount of carbon, about 5%, is substituted for boron. This has led to a better understanding of the superconductivity in this unique compound. The results indicate that, if the current carrying capability and mechanical properties can be further enhanced, carbon-doped MgB_2 could become the next industrial standard superconductor --better, cheaper, and lighter than niobium alloys.
- Wiring for Nanocircuits: Stabilized Silicon Nanotubes. Recent theoretical predictions have indicated that silicon nanotubes can be stabilized by attaching a string of 3d transition elements along the outside of the tube. These same calculations predict that the resulting nanotubes will be strongly conducting -- an important property needed by a candidate material for wiring together nanoelectronic components. The often considered carbon nanotubes, however, can be weakly metallic, semiconducting, or insulating depending on a property that is quite difficult to control-the winding ratio of the tube. The stabilization and metallization of the silicon nanotube can be accomplished with a small amount of nickel, about one nickel atom for every five silicon atoms. The compound tube structure studied is also smaller than most carbon nanotubes.
- Lashing Together Nanoparticles to Make Real Things. Theorists have shown that one can cause nanoparticles to self-assemble into ordered arrays by attaching short polymer strings to the particles to act as tethers. This is important because it is necessary to assemble large numbers of nanometer-

sized particles to create something of size appropriate to our world. It must be done as a loose assembly of the nanoparticles to retain their special properties but often also be arranged in special geometric patterns to realize the desired property. The technique demonstrated by detailed simulations is to attach short polymer strands to the particles at specified points and then let nature take its course. While currently only a theoretical prediction, the scheme is quite feasible and is expected to be in use within two to five years. In the meantime, the theorists are busy developing a "handbook" of how to position the tethers, how long they should be, and what they should be made of to accomplish a particular desired structure.

- A New Class of White Light Phosphors: Advancing the Solid State Lighting Initiative. A new class of tunable, white light emitting phosphors based on single size semiconductor nanoparticles or quantum dots (QDs) has been discovered. This breakthrough meets one of the most critical needs in the Department's Solid-State Lighting Initiative, whose aim is to replace present day highly inefficient light bulbs by solid state lighting devices and thereby have revolutionary effects on conserving electric energy. This accomplishment was made possible by the finding that, for sufficiently small cadmium sulfide and cadmium selenide QDs of diameters two nanometers or less, the onset of light absorption (determined by dot size) and the emission energy, or color (determined by interfacial chemistry), can be independently controlled. The decoupling of these two features allows wide separation of the absorption and emission to eliminate self-absorption of the emitted light, and allows one to tune the emission throughout the visible range from a population of single-size dots. Key to this discovery is the ability to tailor the energies and lifetimes of interface states by the addition of suitable surfactants that bind to selected sites on the QD surface (which determine the emission), or the addition of suitable electron or hole traps (e.g., zinc or sulfide ions, respectively).

- Catalyst Active Sites Imaged in Real Time. The atomic-scale formation and dynamics of active sites on a catalytic surface have been imaged for the first time. Using movies made from a series of state-of-the-art atomic-level scanning tunneling microscope images, the time-dependent behavior of sites on the surface of palladium metal was observed while diatomic hydrogen gas was adsorbed and then dissociated into two hydrogen atoms. The catalytic dissociation of hydrogen on a metal surface is pervasive in catalytic chemistry. Contrary to the prevailing view of the past three decades, it was found that three adjacent and empty surface sites are required for this process to occur - two empty sites are not sufficient. This surprising result calls into question the conventional thinking on the structure of active sites on catalyst surfaces. Further real-time measurements will help establish the molecular-level understanding of the formation of the active sites that determine the catalytic activity of a surface.

- Basic Research Leads to Terabit Memory Devices. A decade-long basic research project has led to the first successful application by industry of a novel approach in nanotechnology, 'molecular self-assembly,' to enable continued miniaturization of semiconductor circuitry such as FLASH memories. The essential element in this new approach lies in directing the orientation of highly-dense arrays of nanoscopic cylindrical domains in thin films of diblock copolymers (BC). Using routine lithographic processes, the BC films are transformed into large area arrays of cylindrical nanopores with very high aspect ratios. Establishing the ability to produce such high density arrays in a simple, robust, and inexpensive manner using conventional processing (new tooling is not required and will not be required with further advances in the self-assembly technique) has broken new ground in fundamental studies of nanoscience and the rapid transfer of this technology to the industrial sector.

- Fundamentals of How Liquid Metals Solidify Answered with Synchrotron Radiation Experiments. Materials properties are determined, in large measure, by the nature of the solidification process.

During the cooling process, the metal atoms in the liquid phase are thought to pack together with almost the same order as the resultant solid. In fact, early experiments demonstrated that liquids cooled far below their melting point still maintain a large degree of disorder. As the temperature is further lowered, a well ordered crystalline solid is eventually reached, but the nucleation pathway to the crystalline form remained a mystery. By combining levitated molten metal drops with a newly developed, in-situ synchrotron x-ray diffraction technique for measuring structure during solidification, investigators have verified for the first time that atoms in a liquid metal arrange themselves with the local symmetry of an icosahedron, a Platonic solid consisting of 20 tetrahedra (4-sided pyramid shaped polyhedra). As cooling proceeds, the icosahedral arrangement transitions to the final crystalline form. This discovery proves that atomic scale structure in the liquid actually plays a role in crystallization, something that is not treated in current nucleation theory.

- X-Ray Microscopy in 3D on a Micron Scale. Metal deformation, ranging from the centuries old heating and beating of sword edges to the rolling of metal sheets in modern industrial mills, is one of the oldest and most important materials processing techniques, yet it remains one of the least understood. Although elaborate recipes have been developed to produce alloys with desired properties, they are all based on expensive and inefficient search and discovery methods. To address this, a new, nondestructive, submicron-resolution 3D x-ray microscopy technique with high-precision nanoscale indentations to study the fundamental aspects of deformation in ductile materials has been developed. X-ray microscopy measurements made using penetrating synchrotron x-ray microbeams are providing detailed, quantitative information on the deformation microstructure for sizes below that of a human hair, but too large for electron microscopy. These results provide previously missing information that is critical for testing advanced theories and computer modeling and for making new materials, with predictable properties, in a more efficient manner.
- Understanding Fundamental Magnetic Properties Could Lead to Sensor Development. Magnetic excitations provide insight into the spin structure and spin dynamics of materials. One material studied exhibits colossal magnetoresistance, a property that makes it interesting for sensor applications. The magnetic structure of this material ($Pr_{0.5}Sr_{0.5}MnO_3$) was determined to be ferromagnetically aligned layers that are coupled antiferromagnetically. The magnetic excitations (also called spin waves) were measured using inelastic neutron scattering at the High Flux Isotope Reactor at Oak Ridge National Laboratory. The spin wave dispersion follows the behavior expected from linear spin wave theory. With refinements in analyzer efficiency and film preparation techniques, the measurement technique will then be applied to thin films. This should allow a search for spin wave excitations in antiferromagnetic films of Fe-Pt.

Selected FY 2004 Facility Accomplishments

- The Advanced Light Source (ALS)
  - New Insertion Device Installed for Ultrafast X-Ray Pulses. Light from a high-power, ultrafast laser will travel with the electron beam through the new permanent-magnet wiggler at the ALS, thereby modulating the energy of a portion of the electron beam. The energy modulation results in a spatial separation of the modulated slice of the beam, which is only 200 femtoseconds long, so that it can be used to generate ultrafast x-ray pulses for experiments at photon energies from 100 eV to10 keV.
  - High-pressure Facility Enables State-of-the-art Geophysics and Materials Research. At the newly commissioned ALS research facility, x-rays from a superconducting bend-magnet source, a high-efficiency micro-focused beamline, and a high-power laser-heated high-pressure cell (diamond

anvil cell) will be used for a wide range of experiments, such as determining the high-pressure/high-temperature phase diagrams and equations of state of materials at pressures up to the Mbar range and at temperatures up to several thousand Kelvin.

- New Research on Solvated or Buried Systems Possible. Real-world materials that inhabit wet environments or are buried in the interior of more complex structures pose challenges to researchers. *In situ* electronic and structural properties of such materials are now accessible due to the high brightness of third-generation synchrotron radiation sources and the development of liquid-cell sample chambers. The technology developed at the ALS has already been demonstrated for the characterization of nanoparticles and opens the way for studies of advanced battery and hydrogen storage material.

- Fast Orbit Feedback Stabilizes Electron Beam Position. Today's synchrotron radiation instrumentation requires that the position of the illuminating x-ray beam be rock solid, which in turn imposes the same condition on the position of the electron beam. ALS scientists and engineers have commissioned a new feedback system (fast orbit feedback) that senses the beam position and sends signals to the control system to correct any vertical and horizontal position errors to within 2 μm and 3 μm, respectively.

▪ The Advanced Photon Source (APS)

- A New Technique for Understanding Materials under Extreme Conditions. Nuclear resonant inelastic x-ray scattering and extreme-brilliance x-ray beams are being used to measure, for the first time, the velocity of sound in tiny samples of materials under extreme conditions. The ability to obtain detailed information from minuscule amounts of materials under extreme conditions is critical to many experiments, from geophysics to national security.

- Taking the Heat from Higher-Brightness X-rays. Two new beamlines require two or three in-line undulators to achieve the required high photon intensity. To accommodate the expected higher APS storage ring beam current and concurrent heat loads that will be more than three times hotter than the surface of the sun, a novel insertion device front end has been developed.

- Powering Up to Higher X-ray Beam Brilliance. Radio frequency (rf) technology at the APS is one of several innovations laying the foundation for an eventual increase in storage ring current to 300 mA. This power exceeds the rf output power of all the TV and radio stations in a major U.S. city such as Washington, D.C., and will provide researchers with more brilliant x-ray beams.

- Glowing Results from a Unique Application of X-ray Fluorescence. The intense photon flux from an APS insertion device beamline has been used for the first application of x-ray-induced fluorescence techniques to perform in-situ measurements in high-pressure metal-halide arcs. These data, not obtainable in any other way, are essential to developing a clearer understanding of high-pressure arc systems, among the most energy-efficient sources of white light.

▪ The National Synchrotron Light Source (NSLS)

- Superconducting Undulator Test Facility Constructed. A state-of-the-art cryogenic Vertical Test Facility was designed and constructed for use in developing superconducting undulators (SCU). This device allows precise magnetic field mapping of superconducting undulator prototypes at cryogenic temperatures and measures thermal performance and quench behavior under realistic operating conditions, including simulated beam heating. A SCU design has been developed which incorporates a novel cryogenic thermal management system to intercept the high beam heat loads expected in future ultra-high brightness synchrotron light sources.

- Hard X-ray Microprobe Completed for Environmental Sciences. A new hard x-ray microprobe beamline, X27A, will provide additional and enhanced x-ray micro-spectroscopy capabilities to the NSLS environmental science user community. The beamline can be operated in three different modes and can focus x-rays to a spot the size of a few microns. The detector array will enable both elemental mapping as well as fluorescence yield x-ray absorption spectroscopy studies of complex environmental samples.
- Infrared Spectrometer Installed on Surface Science Beamline. Corrosion and catalysis involves the interaction between gas molecules and another material such as a metal surface. Infrared spectroscopy from metal surfaces is an important tool for studying the interactions with adsorbed molecules. A portion of the U4IR surface science beamline was re-built to incorporate a new infrared spectrometer. This new spectrometer provides improved spectral resolution, spectral range, and increased collection rates over the previous instrument.
- X-ray Beamline Renovated for Materials Sciences. The X21 hybrid wiggler x-ray beamline and two experimental stations have been substantially rebuilt to accommodate new experimental programs that address elastic x-ray scattering studies of materials under high magnetic fields, thin films grown in-situ, and materials studied with small angle x-ray scattering, with appropriate setups permanently installed in the stations.

▪ The Stanford Synchrotron Radiation Laboratory (SSRL)

- SPEAR3 Project Completed. The four-year SPEAR3 Upgrade Project, jointly funded by the Department of Energy and the National Institutes of Health, was completed on time and within budget (SPEAR stands for the Stanford Positron Electron Accelerating Ring). The 3-GeV SPEAR3 light source produces x-ray beams having 1 to 2 orders of magnitude higher photon brightness than the SPEAR2 accelerator it replaced, enabling enhanced scientific capabilities comparable to those of other third generation light sources.
- SPEAR3 Commissioned and Operation for Users Commenced. The SPEAR3 storage ring was commissioned within a remarkably short time, beginning with equipment turn-on in mid-November 2003, and ending with the first 100-mA beam delivery to users in early March 2004. The speedy commissioning enabled the SSRL user program to begin again only 11 months after the SPEAR2 shutdown.
- First Diffraction Patterns are demonstrated with the SPPS. The first measurements of diffraction patterns from several prototypical samples were achieved at the sub-picosecond pulse source (SPPS). The first signals from the electro-optic pulse length and jitter experiment have been recorded yielding resolution limited pulse lengths of 1 picosecond. The preliminary jitter results indicate root-mean-square timing of the order of 250-300 femtoseconds.
- Source of Excessive Beam Emittance Found. Important progress in understanding the sources of excessive electron beam emittance from a photo-cathode gun has been made at the SSRL Gun Test Facility, setting the path for achieving the design goal for the Linac Coherent Light Source (LCLS) electron gun. The discovery indicates that a time dependent kick significantly increases the projected beam emittance. Eliminating the beam kick will enable operation of the high-charge gun with a sufficiently low emittance for x-ray Free Electron Laser operation at the LCLS.

- The Intense Pulsed Neutron Source (IPNS)
  - IPNS Instruments Upgraded. The IPNS continues to make major instrument upgrades to maintain world class science capabilities for its users: 1) more than one half of the user instruments have migrated to a new data acquisition system that enables faster and more flexible data binning; 2) installation of neutron guides and frame definition choppers has boosted flux on sample for some instruments by 2-20 times; and 3) improved detectors and collimation and larger detector coverage have significantly reduced the time required to collect neutron data. Successful commissioning of a new IPNS target from recycled disks recovered from end-of-life targets has provided a cost effective alternative to the construction of entirely new IPNS targets and enables IPNS operations for an additional six years.
  - IPNS Hosts the National Neutron and X-Ray Scattering School. During the two-week period of August 15-29, 2004, Argonne National Laboratory again hosted the National School on Neutron and X-Ray Scattering. The school continues to attract outstanding graduate students and post-doctoral appointees with 134 applications for the 60 positions available in 2004.
- The Manuel Lujan Jr. Neutron Scattering Center at the Los Alamos Neutron Science Center (LANSCE)
  - Goniometer Installed on Small-Angle Neutron Scattering Instrument. The goniometer is able to position the sample in the neutron beam with any orientation. Thus, it provides for a complete measurement of diffraction space, giving information on the crystal three-dimensional structure over large length scales from 1 to about 100 nm. Research problems that will benefit from this new capability include flux-lattice studies in superconductors, super lattice structures, and self-assembling colloidal structures.
  - Spin Echo Spectrometry Demonstrated. This technique, achieved for the first time at a pulsed neutron source, has application to diffraction problems in nanoscale materials systems and was demonstrated on a dilute solution of 58 nm diameter polystyrene spheres in deuterium oxide.
  - High-Intensity Powder Diffractometer (HIPD) Refurbished. The instrument is now fully operational for studies of atomic and magnetic structure of crystalline and noncrystalline powders, liquids, phase transitions, small samples, and absorbing materials. Due to its very high counting rates, time-resolved measurements are also possible as recently demonstrated in a diffraction study of the curing process of cement.
- The High Flux Isotope Reactor (HFIR)
  - Operational Milestone Celebrated. On April 21, 2004, HFIR began its 400th operating cycle in its 38 year history. The length of an operating cycle depends on the time it takes for the reactor's uranium fuel to become depleted. A celebration marking this anniversary was held on May 15.
  - Neutron Scattering Instruments Upgraded. The upgraded HFIR has state-of-the-art neutron scattering instruments that are among the world's best. In FY 2004, the HB-2B Residual Stress Diffractometer was brought into operation in the HFIR Beam Room. The HB-2D triple-axis monochromator shield was installed at the end of the HB-2 tunnel, and the Reflectometer and SNS Detector Station on this beam tube are operational. The WAND diffractometer, one of the instruments in the US-Japan International Collaboration, will also be operational, completing an important milestone in the HFIR Upgrade project.

- Cold Source Comprehensive Hazards Analysis Completed. One of the premier features of the HFIR upgrade will be the addition of an environment of super-cold liquid hydrogen. This environment literally chills the neutrons so they have less thermal energy with longer wavelengths, which make them valuable tools for the study of larger, more complex atomic and molecular structures. The HFIR Cold Source Comprehensive Hazards Analysis was completed and submitted to DOE in support of the October 4, 2004 milestone.
- Reactor Equipment Upgraded. New Instrument Air System compressors, dryers and receivers were installed in FY 2004. These components replace obsolete equipment and will simplify the system by reducing the number of valves in the system significantly.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Materials Sciences and Engineering Research......	**260,693**	**294,367**	**270,742**
▪ **Structure and Composition of Materials...........**	**22,833**	**31,185**	**26,403**

This activity supports basic research on atomic-scale structure, composition, and bonding and on their relationship to the behavior and performance of materials, predictive theory and modeling, and new materials systems. This activity also supports four electron beam microcharacterization user centers: the Center for Microanalysis of Materials at the University of Illinois, the Electron Microscopy Center for Materials Research at Argonne National Laboratory, the National Center for Electron Microscopy at Lawrence Berkeley National Laboratory, and the Shared Research Equipment Program at Oak Ridge National Laboratory. These centers contain a variety of highly specialized instruments to characterize localized atomic positions and configurations, chemical gradients, bonding forces, etc.

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

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

In FY 2006, funding will continue on advanced instruments with capabilities to characterize and interpret atomic configurations and packing arrangements at the nanoscale with improved resolution and accuracy, including the ability to determine composition, bonding, and physical properties of materials.

The overall decrease in structure and composition of materials is attributable to an increase for research related to the hydrogen economy ($+135,000) and a decrease due to reduced research activities in metal and ceramic grain boundary characterization and FY 2005 one-time increments in areas of transmission electron microscopes ($-4,917,000).

	FY 2004	FY 2005	FY 2006
	(dollars in thousands)		
▪ **Mechanical Behavior and Radiation Effects**.....	**13,444**	**13,469**	**12,221**

This activity supports basic research to understand the deformation, embrittlement, fracture and radiation damage of materials. Concerns include the behavior of materials under repeated or cyclic stress, high rates of stress application as in impact loading, and over a range of temperatures corresponding to the stress and temperature conditions in present and anticipated future energy conversion systems. The objective is to achieve an atomic level understanding of the relationship between mechanical behavior and defects in materials, including defect formation, growth, migration, and propagation. This research aims to build on this atomic level understanding in order to develop predictive models for the design of materials having superior mechanical behavior, with some emphasis on very high temperatures. The focus of basic research in radiation effects is to achieve an atomic-level fundamental understanding of mechanisms of radiation damage and how to design radiation-tolerant materials. Concerns include radiation induced embrittlement and radiation assisted stress-corrosion cracking. Other issues include achieving an atomic level understanding of amorphization mechanisms (transition from crystalline to a non-crystalline phase) and the modification of surface behavior by techniques such as ion implantation.

This program contributes to DOE missions in the areas of fossil energy, fusion energy, nuclear energy, transportation systems, industrial technologies, defense programs, radioactive waste storage, energy efficiency, and environment management. This research helps understand load-bearing capability, failure and fatigue resistance, fracture toughness and impact resistance, high-temperature strength and dimensional stability, ductility or deformability of materials that is critical to their ease of fabrication, and radiation effects including understanding and modeling of radiation damage and surface modification using ion implantation. This activity relates to energy production and conversion through the need for failure resistant materials that perform reliably in the hostile and demanding environments of energy production and use. This program contributes to understanding of mechanical properties of materials and aspects of nuclear technologies ranging from radioactive waste storage to extending the lifetime of nuclear facilities.

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

In FY 2006, there will be a decrease in mechanical behavior and radiation effects research attributable to a reduction in activities related to understanding and inhibiting the degradation of structural materials and a decrease due to the FY 2005 one-time funding enhancement for nanomechanics research ($-1,248,000).

▪ **Physical Behavior of Materials**...........................	**22,148**	**26,657**	**24,512**

This activity supports basic research at the atomic and molecular level to understand, predict, and control physical behavior of materials by developing models for the response of materials to environmental stimuli such as: temperature, electromagnetic fields, chemical environments, and proximity of surfaces or interfaces. Included within the activity are research in aqueous, galvanic, and high-temperature gaseous corrosion and their prevention; photovoltaics and photovoltaic junctions and interfaces for solar energy conversion; the relationship of crystal defects to the superconducting properties for high-temperature superconductors; phase equilibria and kinetics of reactions in

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

materials in hostile environments, such as in the very high temperatures encountered in energy conversion processes; and diffusion and transport of ions in ceramic electrolytes for improved performance in batteries and fuel cells.

Research underpins the mission of DOE by developing the basic science necessary for improving the reliability of materials in mechanical and electrical applications and for improving the generation and storage of energy. With increased demands being placed on materials in real-world environments (extreme temperatures, strong magnetic fields, hostile chemical environments, etc.), understanding how their behavior is linked to their surroundings and treatment history is critical.

Capital equipment is provided for items such as spectroscopic instruments, instruments for electronic and magnetic property measurement, and analytical instruments for chemical and electrochemical analysis.

In FY 2006 the overall decrease in physical behavior of materials is attributable to an increase in research related to the hydrogen economy ($+355,000) and a decrease due to FY 2005 one-time enhancements in areas of organic electronic materials, and electronic and magnetic materials research ($-2,500,000).

	FY 2004	FY 2005	FY 2006
▪ **Synthesis and Processing Science**	**12,710**	**14,271**	**14,771**

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

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

These activities underpin many of the DOE technology programs, and appropriate linkages have been established in the areas of light-weight, metallic alloys; structural ceramics; high-temperature superconductors; and industrial materials, such as intermetallic alloys.

In FY 2006, funding will include continued support for research on nanoscale synthesis and processing. This activity will address the significant experimental and theoretical challenges in understanding what is occurring so that the benefits of nanoscale phenomena can be realized in larger scale components. The properties of materials change dramatically as the grain size in materials approaches the nanometer scale. At conventional grain sizes, a gain in strength of a material typically

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

results in a loss in both ductility and fracture toughness resulting in a brittle material. However, by using nanocomposites and understanding deformation physics, it should be possible to make materials that are strong, tough (resistant to impact fracture), and ductile. There is also great need for nanoparticles of uniform size, composition, and surface stability because experiments have shown that fracture toughness may undergo a profound increase as the grain size falls below 10 to 50 nm in high-temperature structural ceramics. These materials might be used in advanced fuel efficient engines, turbines, and machine cutting tools.

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

In FY 2006 the overall increase in synthesis and processing science is attributable to a decrease due to the reduced research in the area of welding and joining of materials and FY 2005 one-time increments in areas of guided self-assembly ($-1,258,000), and an increase for research related to the hydrogen economy ($+125,000) and nanoscale science focusing on theory, modeling an computation ($+1,633,000).

	FY 2004	FY 2005	FY 2006
▪ **Engineering Research**	**10,975**	**7,902**	**5,000**

The performance, safety, and economics of fission, fusion, fossil, and transportation energy conversion systems depend on a thorough understanding of heat transfer in regimes of complex, multi-phase fluid flow and the ability to provide reliable early warning of impending catastrophic fracture or other failure. This activity supports fundamental atomic or nanoscale studies of the conduction of heat in terms of the interactions of phonons (or crystal lattice vibrations) with crystalline defects and impurities and the transfer of mass and energy in turbulent flow in geometrically constrained systems and the mechanics of nanoscale systems.

On-going activities in FY 2006 will include research in the mechanics of nanoscale systems including nanotube driven motors and nano-systems containing both physical and biological components, nanoindentation, and fluid behavior during solidification including the competition between amorphous and crystalline phase development. Research in heat transfer, multiphase fluid flow, and granular materials will be decreased or terminated. ($-2,902,000).

	FY 2004	FY 2005	FY 2006
▪ **Neutron and X-ray Scattering**	**44,928**	**49,970**	**44,058**

This activity supports basic research in condensed matter physics and materials physics using neutron and x-ray scattering capabilities, primarily at major BES-supported user facilities. Research seeks to achieve a fundamental understanding of the atomic, electronic, and magnetic structures of materials as well as the relationship of these structures and excitations to the physical properties of materials. The increasing complexity of such energy-relevant materials as superconductors, semiconductors, and magnets requires ever more sophisticated neutron and x-ray scattering techniques to extract useful knowledge and develop new theories for the behavior of these materials. Both ordered and disordered materials are of interest as are strongly correlated electron systems, surface and interface phenomena, and behavior under environmental variables such as temperature, pressure, and magnetic field. X-ray and neutron, together with the electron scattering probes supported under Structure and Composition of Materials, are the primary tools for characterizing the atomic, electronic, and magnetic structures of materials.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

Research in the areas of nanostructured materials and novel hydrogen storage media will be continued using the structural and chemical information garnered from x-ray and especially neutron scattering. Structural studies on carbon-based hydrogen storage media-such as nanotubes, nanohorns, fullerenes, and nanoscale hydrides also will be performed to reveal the site of hydrogen incorporation and the mechanisms of hydrogen storage. An additional $303,000 will be applied to this research.

In FY 2006 the overall decrease in neutron and x-ray scattering is attributable to an increase in research related to the hydrogen economy ($+303,000), and a decrease in neutron powder diffraction and due to FY 2005 one-time increments in areas of instrumentation physics and neutron scattering research ($-6,215,000).

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

▪ **Experimental Condensed Matter Physics**	**42,631**	**45,647**	**42,004**

This activity supports condensed matter physics with emphases in electronic structure, surfaces, and interfaces and new materials. Research includes measurements of the properties of solids, liquids, glasses, surfaces, thin films, artificially structured materials, self-organized structures, and nanoscale structures. This activity includes the design and synthesis of new materials with new and improved properties. These materials include magnetic materials, superconductors, semiconductors and photovoltaics, liquid metals and alloys, and complex fluids. The development of new techniques and instruments including magnetic force microscopy, electron microscopic techniques, and innovative applications of laser spectroscopy is a major component of this activity. Measurements are made under extreme conditions of temperature, pressure, and magnetic field.

This research is aimed at a fundamental understanding of the behavior of materials that underpin DOE technologies. This activity supports research in photovoltaics, superconductivity, magnetic materials, thermoelectrics, and optical materials which underpin various technology programs in Energy Efficiency and Renewable Energy (EE/RE). Research in superconductivity and photovaltaics especially is coordinated with the technology programs in EE/RE. In addition, this activity supports the strategically important information technology and electronics industries in the fields of semiconductor physics, electronics, and spintronics research. The petroleum recovery efforts of Fossil Energy (FE) and the clean-up efforts of Environmental Management (EM) programs are supported through research on granular materials and on fluids.

In FY 2006, funding provides support for investigation of fundamental questions in condensed matter physics at the nanoscale. As the size of a nanoscale structure becomes less than the average length for scattering of electrons or phonons, new modes of transport for electrical current and/or heat may become possible. Also thermodynamic properties, including collective phenomena and phase transitions such as ferromagnetism, ferroelectricity, and superconductivity can change when structures contain a smaller number of atoms, with a much greater proportion of surface atoms. The potential impacts of understanding the physics are very significant. For example, nanoscale structures provide a path toward the next generation of magnets for memory, more efficient electric motors, better thermoelectric materials, and materials for more efficient solar energy conversion. Research efforts for the development of nanomaterials for both energy conversion and hydrogen energy

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

storage, which exhibit size-dependent properties that are not seen in macroscopic solid state materials will be continued. Enhanced electrical, thermal, mechanical, optical, and chemical properties have shown that these new nanomaterials could lead to dramatic improvements in the technologies relevant to fuel cells, batteries, capacitors, nanoelectronics, sensors, photovoltaics, thermal management, super-strong lightweight materials, hydrogen storage, and electrical power transmission.

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

The overall decrease for experimental condensed matter physics is attributable to an increase for research related to the hydrogen economy ($+296,000) and a decrease due to FY 2005 one-time increments in crystal growth, scanning tunneling microscopy, transmission electron microscopy, and correleated electron materials research and reduced research activities in thermal physics ($-3,939,000).

▪ **Condensed Matter Theory**..................................	**18,126**	**18,872**	**19,975**

This activity supports basic research in theory, modeling, and simulations, and it complements the experimental work. A current major thrust is in nanoscale science where links between the electronic, optical, mechanical, and magnetic properties of nanostructures and their size, shape, topology, and composition are not well understood. For the simplest semiconductor systems, carbon nanotubes, and similar “elementary” systems, there has been considerable progress. However, for more complex materials and hybrid structures, even the outlines of a theory remain to be made. Computer simulations will play a major role in understanding materials at the nanometer scale and in the development “by design” of new nanoscale materials and devices. The greatest challenges and opportunities are in the transition regions where nanoscale phenomena are just beginning to emerge from the macroscopic and microscale regimes.

The Computational Materials Sciences Network supports cooperative research teams for studies requiring numerous researchers with diverse expertise. Examples include fracture mechanics – understanding ductile and brittle behavior; microstructural evolution in which microstructural effects on the mechanics of materials; magnetic materials across all length scales; excited state electronic structure and response functions; and strongly correlated electron systems.

This activity also supports the Center for X-ray Optics at LBNL, and the Center for Synthesis and Processing of Advanced Materials, which consists of collaborating projects at national laboratories, universities, and industry.

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

In FY 2006, the overall increase for theoretical condensed matter physics is attributable to an increase for research related to theory, modeling, and computation in nanoscience ($+3,000,000) and to hydrogen production, storage, and use ($+125,000) and a decrease due to FY 2005 one-time enhancements in areas of materials theory, and improvements to existing instruments, including computer clusters ($-2,022,000).

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Materials Chemistry**...	**40,338**	**45,422**	**41,740**

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

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

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

In FY 2006, funding will continue to explore multi-disciplinary approaches (with biology, chemistry, physics and computational science playing major roles) to model, design and synthesize new and novel materials. Also of interest is the development of new organic electronic materials with novel magnetic, conducting, and optical properties; single crystal growth of advanced materials that will lead to better characterization, and consequently, better understanding of their properties; and polymer interfaces. The overall decrease for materials chemistry is attributable to an increase for research related to basic research for hydrogen production, storage, and use ($+500,000) and a decrease due to FY 2005 one-time increments in areas of nanoscale polymer materials research, and improvements to existing instruments, including nuclear magnetic resonance and novel atomic force microscopes, and a reduction for smaller group activities ($-4,182,000), including single investigator projects at DOE national laboratories.

▪ **Experimental Program to Stimulate Competitive Research (EPSCoR)**......................	**7,673**	**7,643**	**7,280**

This activity supports basic research spanning the complete range of activities within the Department in states that have historically received relatively less Federal research funding. The EPSCoR states are Alabama, Alaska, Arkansas, Delaware, Hawaii, Idaho, Kansas, Kentucky, Louisiana, Maine, Mississippi, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, Vermont, West Virginia, Wyoming, the Commonwealth of Puerto Rico, and the U.S. Virgin Islands. The work supported by the EPSCoR program includes research in materials sciences, chemical sciences, biological and environmental sciences, high energy and nuclear physics, fusion energy sciences, fossil energy sciences, and energy efficiency and renewable energy sciences. The following table shows EPSCoR distribution of funds by state. The decrease in EPSCoR is attributable to a reduction in new competitions in FY 2006 ($-363,000).

EPSCoR Distribution of Funds by State

	(dollars in thousands)		
	FY 2004 Estimate	FY 2005 Estimate	FY 2006 Estimate
Alabama	987	510	600
Alaska	0	0	0
Arkansas	140	0	135
Delaware[a]	0	0	0
Hawaii[b]	0	0	0
Idaho	328	102	375
Kansas	527	560	135
Kentucky	247	224	0
Louisiana	647	198	462
Maine	0	0	0
Mississippi	578	535	132
Montana	515	375	375
Nebraska	0	0	125
Nevada	0	0	0
New Mexico[b]	135	0	135
North Dakota	410	139	273
Oklahoma	525	135	350
Puerto Rico	375	375	375
South Carolina	854	266	535
South Dakota	125	0	125
Tennessee[a]	0	0	0
Vermont	877	709	0
US Virgin Islands[a]	0	0	0
West Virginia	248	201	90
Wyoming	130	130	140
Technical Support	25	110	110
Other[c]	0	3,074	2,808
Total	7,673	7,643	7,280

[a] Delaware, Tennessee, and U.S. Virgin Islands became eligible for funding in FY 2004.
[b] Hawaii and New Mexcio became eligible for funding in FY 2002.
[c] Uncommitted funds in FY2005 and FY2006 will be competed among all EPSCoR states.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Neutron Scattering Instrumentation at the High Flux Isotope Reactor**	**2,000**	**2,000**	**2,000**

Capital equipment funds are provided for new and upgraded instrumentation, such as spectrometers, diffractometers, and detectors.

▪ **Linac Coherent Light Source (LCLS)**	**2,000**	**4,000**	**0**

Research and development (R&D) funds are provided to support the physics design of several key LCLS components: the photocathode gun, the linac, the undulator, and the beam optics. These R&D activities will be carried out at SLAC and other collaborating institutions in order to reduce the technical risk and provide more confidence in the project's cost and schedule estimates prior to establishing a project performance baseline. The completion of funding is in accordance with the approved project schedule.

▪ **Nanoscale Science Research Centers**	**400**	**600**	**993**

Funds are provided for three Nanoscience Research Centers to support pre-operational activities leading up to the start of research operations. These Centers are the Center for Nanophase Materials Sciences (CNMS) located at ORNL, the Molecular Foundry located at LBNL, and the Center for Integrated Nanotechnologies (CINT) located at Sandia National Laboratories and Los Alamos National Laboratory.

▪ **The Center for Nanoscale Materials**	**10,000**	**12,000**	**14,000**

Funds are provided for a Major Item of Equipment (MIE) with a total estimated cost of $36,000,000 for instrumentation, including clean rooms, for the Center for Nanoscale Materials at Argonne National Laboratory. The instrumentation will be contained in a new building, which is being constructed by the State of Illinois for the Center at a cost of $36,000,000 and which will be dedicated to the Center operations. The building will be appended to the Advanced Photon Source. Included within the Center's instrument suite will be an x-ray nanoprobe beamline at the Advanced Photon Source. This beamline will be the highest spatial resolution instrument of its kind in the world, which will permit nondestructive examination of magnetic, electronic, and photonic materials important both for basic science and as foundations for future nanotechnologies. The Center will build on ANL's recognized strengths in magnetism, superconductivity, and novel materials with "spintronic" functionality.

▪ **Instrumentation for the Spallation Neutron Source**	**7,387**	**7,643**	**8,079**

Funds are provided for a MIE with a total estimated cost in the range of $50,000,000 to $75,000,000 for five instruments for the Spallation Neutron Source that will be installed after the SNS line item project is completed in FY 2006. These instruments will complement the initial suite of five instruments that are being built as part of the SNS construction project, which has capacity for 24 instruments. The instrument concepts for the MIE project were competitively selected using a peer review process. The project will be managed by Oak Ridge National Laboratory with participation by both Argonne and Brookhaven National Laboratories as well as by the State University of New York at Stony Brook. The TEC range will be narrowed to a cost and schedule performance baseline

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

following completion of Title I design and External Independent Reviews. It is anticipated that these five instruments will be installed at the SNS on a phased schedule between FY 2007 – 2011.

▪ **Research on Instrumentation for the Linac Coherent Light Source (LCLS)**	**0**	**1,500**	**1,500**

Funds are provided to continue R&D on instrumentation for the LCLS. These instruments will complement the instrument that is being built as part of the LCLS construction project. This R&D activity will evolve after determination of the scope of the project, i.e., the number and type of instruments to be fabricated. The instrument concepts that are being supported with these funds will be competitively selected using a peer review process. The activity is patterned after that described above for the SNS. The project will be managed by the Stanford Linear Accelerator Center with participation by partners as determined by the peer review process.

▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	**3,100**	**5,586**	**6,206**

Funds are provided for a MIE with a Total Estimated Cost in the range of $11,200,000 to $13,500,000 and a Total Project Cost in the Range of $25,000,000 to $30,000,000. The TEAM project will construct and operate a new aberration-corrected electron microscope and make this capability widely available to the materials and nanoscience communities. The projected improvement in spatial resolution, contrast, sensitivity, and the flexibility of design of electron optical instruments will provide unprecedented opportunities to observe directly the atomic-scale order, electronic structure, and dynamics of individual nanoscale structures. The TEAM instrument will serve as a platform for future aberration-corrected instruments optimized for different purposes such as wide-gap in-situ experimentation, ultimate spectroscopy, ultrafast high-resolution imaging, synthesis, field-free high resolution magnetic imaging, diffraction and spectroscopy, and other extremes of temporal, spectral, spatial or environmental conditions.

Facilities Operations	**298,138**	**325,242**	**457,069**
▪ **Operation of National User Facilities**	**298,138**	**325,242**	**457,069**

As noted earlier, in order to accomplish the highest-priority goals, some difficult choices had to be made. In particular, the BES support for the Radiochemical Engineering and Development Center at Oak Ridge National Laboratory is terminated. The operations of the remaining facilities are funded at about the same level as in FY 2005, which will decrease the available beam time and service to users by about ten percent. In general, the decrease in funding from FY 2005 to FY 2006 represent one-time increments in capital equipment and other specialized increments in FY 2005. These include: Advanced Light Source, Advanced Photon Source, National Synchrotron Light Source, Stanford Synchrotron Radiation Laboratory, and High Flux Isotope Reactor. The Spallation Neutron Source and the Nanoscale Science Research Centers operate at their planned FY 2006 levels. In addition, funds are provided to partially support operation of the SLAC linac previously fully funded by the High Energy Physics (HEP) program. This marks the beginning of a 3-4 year transition of programmatic ownership for SLAC linac operations from HEP to BES as the LCLS project proceeds. The Combustion Research Facility is funded in the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. The facility operations budget request, presented in a consolidated manner

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

later in this budget, includes operating funds, capital equipment, and accelerator and reactor improvements (AIP) funding under $5,000,000. AIP funding will support additions and modifications to accelerator and reactor facilities that are supported in the Materials Sciences and Engineering subprogram. General plant project (GPP) funding is also required for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $5,000,000. Capital equipment is needed at the facilities for items such as beam monitors, interlock systems, vacuum systems, beamline front end components, monochromators, and power supplies. A summary of the funding for the facilities included in the Materials Sciences and Engineering subprogram is provided below.

Facilities

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Advanced Light Source	43,937	45,600	42,367
Advanced Photon Source	95,740	99,950	98,000
National Synchrotron Light Source	37,398	37,400	37,400
Stanford Synchrotron Radiation Laboratory	29,670	30,654	28,300
High Flux Isotope Reactor	40,284	46,930	40,032
Radiochemical Engineering Development Center	6,100	4,500	0
Intense Pulsed Neutron Source	16,768	17,055	17,055
Manuel Lujan, Jr. Neutron Scattering Center	9,844	10,053	10,300
Spallation Neutron Source	18,397	33,100	106,872
Center for Nanophase Materials Sciences	0	0	18,086
Center for Integrated Nanotechnologies	0	0	12,709
Molecular Foundry	0	0	8,554
Center for Nanoscale Materials	0	0	3,894
Linac Coherent Light Source (LCLS)	0	0	3,500
Linac for LCLS	0	0	30,000
Total, Facilities	298,138	325,242	457,069

SBIR/STTR	**0**	**15,523**	**18,332**

In FY 2004, $12,433,000 and $1,492,000 were transferred to the SBIR and STTR programs, respectively. The FY 2005 and FY 2006 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

Total, Materials Sciences and Engineering	**558,831**	**635,132**	**746,143**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Materials Sciences and Engineering Research	
▪ **Structure and Composition of Materials**	
Overall decrease in structure and composition of materials research because of increase for research related to the hydrogen economy ($+135,000) and decrease in metal and ceramic grain boundary characterization research and FY 2005 one-time increments in areas of electron microcopy and improvements to existing instruments ($-4,917,000).	-4,782
▪ **Mechanical Behavior and Radiation Effects**	
Decrease in mechanical behavior and radiation effects research because of reduction in degradation of structural materials research and FY 2005 one-time increment for nanomechanics research	-1,248
▪ **Physical Behavior of Materials**	
Overall decrease in physical behavior of materials research because of increase for research related to the hydrogen economy ($+355,000) and reduction due to FY 2005 one-time research increments ($-2,500,000)	-2,145
▪ **Synthesis and Processing Science**	
Overall increase because of decrease in research in the area of welding and joining of materials ($-1,258,000) and increase for research related to the hydrogen economy ($+125,000) and nanoscale science focusing on theory, modeling and computation ($+1,633,000)	+500
▪ **Engineering Research**	
Decrease in engineering research because of decrease for research activities in heat transfer, multiphase fluid flow, and granular materials	-2,902
▪ **Neutron and X-ray Scattering**	
Overall decrease in neutron and x-ray scattering research because of increase for research related to the hydrogen economy ($+303,000) and decrease in neutron powder diffranction and due to FY 2005 one-time research increments ($-6,215,000)	-5,912
▪ **Experimental Condensed Matter Physics**	
Overall decrease in experimental condensed matter physics research because of increase for research related to the hydrogen economy ($+296,000) and decrease in thermal physics research due to FY 2005 one-time research increments ($-3,939,000)	-3,643

	FY 2006 vs. FY 2005 ($000)
▪ **Condensed Matter Theory**	
Increase in condensed matter theory research because of increase for research related to theory, modeling, and computation in nanoscience ($+3,000,000) and hydrogen production, storage, and use ($+125,000) and reduction due to FY 2005 one-time research increments ($-2,022,000)	+1,103
▪ **Materials Chemistry**	
Overall decrease in materials chemistry research because of increase for research related to the hydrogen economy ($+500,000) and reduction for smaller group activities and FY 2005 one-time research increments ($-4,182,000).	-3,682
▪ **Experimental Program to Stimulate Competitive Research (EPSCOR)**	
Decrease in EPSCoR because of reduction in new competitions in FY 2006.	-363
▪ **Linac Coherent Light Source**	
Decrease for research and development per schedule for the Linac Coherent Light Source.	-4,000
▪ **Nanoscale Science Research Centers**	
Increase for other project costs per schedule associated with the Nanoscale Science Research Centers.	+393
▪ **The Center for Nanoscale Materials**	
Increase for MIE for the ANL Center for Nanoscale Materials.	+2,000
▪ **Instrumentation for the Spallation Neutron Source**	
Increase for Instrumentation for the Spallation Neutron Source.	+436
▪ **Transmission Electron Aberration Corrected Microscope (TEAM)**	
Increase for MIE for the Transmission Electron Aberration Corrected Microscope.	+620
Total, Materials Sciences and Engineering Research	**-23,625**
Facilities Operations	
▪ **Operation of National User Facilities**	
Decrease for the ALS as a result of a one time FY 2005 increment for modifications to permit eventual top-up mode injection, which will permit stable x-ray beam intensities rather than the current gradual decline in x-ray beam intensity over the period of several hours.	-3,233
Decrease for the Advanced Photon Source as a result of one-time FY 2005 increment for beamline modifications	-1,950

	FY 2006 vs. FY 2005 ($000)
Decrease for Stanford Synchrotron Radiation Laboratory as a result of one-time FY 2005 increment for optics and beamline modifications to take advantage of the increased brightness following the SPEAR 3 upgrade	-2,354
Decrease for High Flux Isotope Reactor as a result of one-time FY 2005 increment for fuel purchases, maintenance, and instrument modifications	-6,898
Decrease due to termination of BES support for the Radiochemical Engineering Development Center. This marks the beginning of a consolidation of hot-cell activities at ORNL, which will subsequently be funded by other customers	-4,500
Increase for the Manuel Lujan Jr., Neutron Scattering Center for operations	+247
Increase for the Spallation Neutron Source to begin operations	+73,772
Increase for the Center for Nanophase Materials Sciences to begin operations	+18,086
Increase for the Center for Integrated Nanotechnologies to begin operations	+12,709
Increase for the Molecular Foundry to begin operations	+8,554
Increase for the Center for Nanoscale Materials to begin operations	+3,894
Increase for the Linac Coherent Light Source Other Project Costs per FY 2006 project datasheet. These funds will be used to start commissioning of the injector linac subsystems, primarily the laser dedicated to the photocathode gun. These commissioning activities will also involve preparing the applications software and other activities that will ultimately be needed to commission the LCLS linac	+3,500
Increase for SLAC Linac in support of the Linac Coherent Light Source. This marks the beginning of the transition to BES the LCLS operations at SLAC	+30,000
Total, Facilities Operations	**+131,827**
SBIR/STTR	
Increase in SBIR/STTR funding because of an increase in total operating expense funding	+2,809
Total Funding Change, Materials Sciences and Engineering	**+111,011**

Chemical Sciences, Geosciences, and Energy Biosciences

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Chemical Sciences, Geosciences, and Energy Biosciences					
Chemical Sciences, Geosciences, and Energy Biosciences Research	207,886	227,465	210,290	-17,175	-7.6%
Facilities Operations	5,892	6,169	6,169	0	0.0%
SBIR/STTR	0	5,841	5,342	-499	-8.5%
Total, Chemical Sciences, Geosciences, and Energy Biosciences	213,778	239,475	221,801	-17,674	-7.4%

Description

Support is provided in the broad chemical sciences for basic research in atomic, molecular and optical science; chemical physics; photochemistry; radiation chemistry; physical chemistry; inorganic chemistry; organic chemistry; analytical chemistry; separation science; heavy element chemistry; geochemistry; geophysics; and physical biosciences.

Benefits

Ultimately, research in chemical sciences leads to the development of such advances as efficient combustion systems with reduced emissions of pollutants; new solar photoconversion processes; improved catalysts for clean and efficient production of fuels and chemicals; and better separations and analytical methods for applications in energy processes, environmental remediation, and waste management. Research in geosciences contributes to the solution of problems in multiple DOE mission areas, including reactive fluid flow studies to understand contaminant remediation; seismic imaging for reservoir definition; and coupled hydrologic-thermal-mechanical-reactive transport modeling to predict repository performance. Research in biosciences provides the foundation for new biological, biomimetic, and bioinspired paths to solar energy conversion, fuels and chemical feedstock production, chemical catalysis, and materials synthesis.

Supporting Information

This research seeks to understand chemical reactivity through studies of the interactions of atoms, molecules, and ions with photons and electrons; the making and breaking of chemical bonds in the gas phase, in solutions, at interfaces, and on surfaces; and energy transfer processes within and between molecules. In geosciences, support is provided for mineral-fluid interactions; rock, fluid, and fracture physical properties; and new methods and techniques for geosciences imaging from the atomic scale to the kilometer scale. In the area of biosciences, support is provided for molecular-level studies on solar energy capture through natural photosynthesis; the mechanisms and regulation of carbon fixation and carbon energy storage; the synthesis, degradation, and molecular interconversions of complex hydrocarbons and carbohydrates; and the study of novel biosystems and their potential for materials synthesis, chemical catalysis, and materials synthesized at the nanoscale.

This subprogram provides support for chemistry equal to that of the National Science Foundation. It is the Nation's sole support for heavy-element chemistry, and it is the Nation's primary support for homogeneous and heterogeneous catalysis, photochemistry, radiation chemistry, separations and analysis, and gas-phase chemical dynamics.

Selected FY 2004 Research Accomplishments

- Potential for Greatly Enhanced Efficiency in Nanocrystalline Solar Cells. An incident solar photon striking a semiconductor solar cell normally produces a single electron-hole pair (exciton) and some excess heat. Experimentalists have recently demonstrated that two or more excitons can be created by absorption of a single photon in an array of lead-selenide nanocrystals. This process is called "impact ionization" and is observed when the photon energy is greater than three times the band gap of the nanocrystal. Multiple excitons from a single photon are formed on the picosecond time scale, and the process occurs with up to 100% efficiency depending on the excess energy of the absorbed photon. If this process could be translated into an operational solar cell, the gain in efficiency for converting light to electrical current would be greater than 35%.
- High Order Harmonic Generation Using Ions. High harmonic generation (HHG) is a process in which highly nonlinear optical effects, driven by ultrafast, intense laser pulses in an atomic gas, are used to turn visible bursts of photons into bursts in the extreme ultraviolet and soft x-ray spectral regions. There is a cutoff at high frequencies for HHG that is determined by the ionization potential of the atom and by defocusing and phase mismatch of the pump-laser beam due to ionization. Recent experiments have significantly extended the range of HHG to photon energies up to 250 eV through the use of atomic ions, which have higher ionization potentials and are thus capable of producing more energetic harmonic orders. In this work an ultrashort, intense optical laser pulse was focused into a hollow fiber filled with low-pressure argon gas. The fiber serves as a waveguide to phase-match the fundamental excitation pulse with the HHG soft x-ray pulse. This work demonstrates that HHG from ions can extend laser-based, coherent up-conversion into the soft x-ray region of the spectrum.
- Manipulation of Carbon Monoxide Oxidation to Carbon Dioxid. The formation of a chemical bond involves the approach of two reactants to short distances so that a new bond can form. How close do the two reactants need to be for them to interact with each other? In this novel experiment, a single carbon monoxide (CO) molecule on a surface was pushed toward two oxygen (O) atoms that were formed in the dissociation of O_2 by tunneling electrons. Using inelastic electron tunneling spectroscopy in a cryogenically cooled microscope, the hindered rotational mode of the CO molecule was measured as its distance from the two O atoms decreased. The change in this vibrational energy signaled the onset of a significant CO-O interaction prior to the formation of carbon dioxide (CO_2). A shift of 20% in the hindered rotation energy was observed when the CO molecule was within 2.50 Å from each of the two O atoms. Spatially resolved mapping of the hindered rotational mode led to a tilted CO in the O-CO-O complex. The controlled positioning of the two reactants allowed direct visualization of the chemistry. This research probed individual reactive encounters of the type that constitute a surface-mediated catalytic process. Exacting control of catalysis will require such molecular-level characterization.
- Direct Numerical Simulations of Homogeneous Charge Compression Ignition. Homogeneous charge compression ignition (HCCI) has the potential to reduce nitrogen oxide and particulate emissions from internal combustion engines while improving overall efficiencies. A major challenge posed by

this method of combustion is control of the heat release rate, and in particular, a means to spread the heat rate out in time to suppress the occurrence of damaging engine knock. Direct numerical simulations (DNS) of lean hydrogen-air ignition at high pressure and constant volume in the presence of temperature inhomogeneities are helping researchers understand the HCCI combustion process. Starting from an initial distribution of fluctuating temperatures at high pressure, the evolution of localized ignition sites was studied in a constant volume DNS with detailed hydrogen/air reaction kinetics. For the first time, numerical simulations revealed that flame front and spontaneous ignition propagation can coexist in this environment. The simulations showed that the local nature of the ignition propagation is primarily dependent upon the inverse of the local temperature gradient. Criteria were developed from the DNS data (e.g., speed of the ignition front and a critical temperature gradient at the front) to distinguish between the different modes of propagation.

- Charge Separation by Carbon Nanotube/Ferrocene Nanohybrids. Carbon nanotubes, which are chemically stable and electrically conducting, have been modified for the first time by attachment of electron donors, in this case, ferrocene molecules. When excited with visible light, these carbon nanotube-ferrocene hybrids exhibit intramolecular electron transfer to yield long-lived charge-separated species. The carbon nanotube serves as the electron acceptor in the donor-acceptor ensemble, distributing the charge over its extended π-electronic system. The separation of charge is sufficiently long lived to show promise for future development of solar photoelectrochemical cells based on modified carbon nanotubes.
- They Bend Before They Break: Fast Scission of Chemical Bonds. Bond-breaking reactions in liquid solution which are so fast that the rates could not previously be measured, have recently been studied at the new picosecond Laser-Electron Accelerator Facility (LEAF) at Brookhaven National Laboratory. A large class of molecules known as aryl halides was studied, in which a halogen atom, such as chlorine or bromine, dissociates from a sizable planar ring structure, breaking its bond. The newly measured rates can only be explained theoretically if the bond breaks by the halogen atom bending out of plane by about 30 degrees before bond breaking, in a bent transition state. Such fundamental knowledge of the reaction mechanism may lead to improvements in energy efficiency and fewer toxic by-products in large-scale industrial processing.
- Protein-Nanoparticle Hybrid Systems for Light Energy Conversion. Novel protein-nanoparticle hybrid assemblies have been developed that employ semiconductor nanoparticles for initial light-induced charge separation and biomolecules for subsequent chemical/electrical conversion. The end-to-end, wire-like nanorod structures are based on nanoscale metal oxide particles, in which the ability to systematically manipulate size and shape of the nanoparticles was exploited in synthesis of axially anisotropic tubes, cubes, rods, or stars. The nanoparticles were oriented into organized architectures using biolinkers, such as the biotin molecule, that bind strongly to the protein, avidin. Photoexcitation of the wire-like architecture resulted in charge separation originating at the tips of the nanorods: the photogenerated electrons being localized at the semiconductor, and holes at the protein. Thus, a rational design of protein-nanoparticle hybrid architectures enables coupling of photoinduced charge separation in nanocrystallites with the charge-transfer induced chemistry on proteins. The hybrid architectures and ensuing chemistries can either use or alter protein functionality, and could be used for construction of solar-based molecular machines.
- Reverting Carbon Dioxide into Valuable Chemicals. An inexpensive, low-temperature synthetic route for the conversion of carbon dioxide into useful chemicals and fuels is a long-standing

challenge. Despite extensive research, current catalysts still use expensive complexes of platinum-group metals. Recent work has led to a breakthrough in the catalytic addition of hydrogen to carbon dioxide to produce formic acid. Using sophisticated high-throughput techniques to rapidly search for promising catalytic structures, investigators have identified the broadest range to date of hydrogenation catalysts that can sustain high activity for many cycles. These structures consist of phosphine-complexes of copper, chromium, iron, indium, molybdenum, niobium, nickel, or tungsten, all of which are abundant and inexpensive metals. Detailed structural and mechanistic studies have led to even further improvement of the activity and durability by surrounding the metal centers with ligands designed to provide optimum electronic structure while protecting the metals from degradation. The new nickel, copper, and iron phosphine-cyano complexes carry out the production of formic acid at 40 bar and 50^{o}Celsius with limited deactivation for periods of days.

- Pure Hydrogen from Alcohol through Microsecond Catalysis. Researchers have recently shown that it is possible to selectively extract pure hydrogen from ethanol, a renewable fuel made from biomass, in a matter of microseconds. The process is based on a high-temperature ceramic catalyst containing rhodium metal and cerium oxide. At about 800^{o}C, wet ethanol, contacted with the catalyst for about one microsecond, undergoes oxidative dehydrogenation to hydrogen and carbon dioxide, with 95% conversion and 100% selectivity to hydrogen. This remarkable catalytic performance and the low-cost wet alcohol source could result in an economically feasible hydrogen production process for the future, especially as many of these very rapid oxidation reactions are self-sustaining even at 800^{o}C or higher and do not require external heat sources. Advances in this hydrogen production process might provide an alternative to steam reformation of hydrocarbons as a source of hydrogen.
- Benign Polymerization Chemistry Leads to New Polymers. The demand for polymeric materials continues to rise at an impressive rate and, in the near future, environmental conservation may become a major constraint in this expansion. Researchers have long pursued catalysts that take molecules derived from biomass, such as sugars, alcohols, and esters, and convert them with high yield and no waste into synthetic plastics, such as polyethers, polyesters, and polycarbonates, with controlled characteristics. Besides having appropriate thermal and mechanical properties, a significant fraction of future polymers should be biodegradable or biocompatible for use in large-scale packaging or in smaller-scale biomedical applications: drug release membranes, synthetic tissue, and sutures. Recently, investigators have successfully synthesized a family of metal alkoxide catalysts that produce polyesters and blends via ring-opening polymerization of cyclic esters derived from renewable sources. Examples are the synthesis of polylactides from lactides derived from corn and the formation of polycarbonates by ring-opening copolymerization of epoxides-oxiranes and carbon dioxide. The latter is a chemically benign alternative to the current technology for polycarbonate synthesis that uses phosgene, a highly poisonous gas. Through mechanistic, microstructural, and kinetic studies, these investigators are arriving at fundamentally new rules and new catalysts for transformations of oxygenated molecules that may dramatically change the landscape of polymerization chemistry.
- Fundamental Studies on Crown Ethers Benefit Cleanup of Nuclear Waste at Savannah River. Fundamental research has provided the foundation enabling innovative technology for nuclear-waste cleanup at the Savannah River Site (SRS). In early 2004, a large contract was awarded for the design, construction, and commissioning of the Salt Waste Processing Facility (SWPF) to clean up a major portion of some of the nation's most dangerous Cold War era nuclear waste stored at the SRS. Approximately 34 million gallons of waste from nuclear-weapons production are stored in tanks at

the SRS. Over 31 million gallons of that waste is solid or dissolved salts in which the fission product cesium-137 comprises more than 98% of the total radioactivity in the salt. In 2001, the Office of Environmental Management chose the Caustic-Side Solvent eXtraction (CSSX) process developed at Oak Ridge National Laboratory for removing cesium-137 from the waste in the SWPF. The selection followed an intensive period of evaluating candidate technologies by a multi-site team of scientists and engineers over a four-year period. Selection was based on the ability of candidate technologies to meet difficult processing requirements, including the ability to remove 99.9975% of the cesium-137 from the waste. Such extraordinary performance requires extraordinary chemistry, which had its roots in fundamental research which focused on the principles of host-guest chemistry, emphasizing the synthesis of tailored molecules that selectively bind (or host) target species. The understanding of host-guest chemistry from this research led to the ability to design the synthesis of crown ethers with appropriate architecture to complex with alkali metal ions to effect extraction with high selectivity.

- Improved Analysis for the Next Generation of Electronic Devices. New research has shown that by covalent Fluorescent Labeling of Surface Species (FLOSS), the inherent sensitivity of fluorescence spectroscopy can be exploited to identify and quantify low concentration functional groups on surfaces. FLOSS enables the detection of surface chemical groups as low as 10^{11} molecules/cm^2 (0.01% of the surface) by specific covalent attachment of fluorescent chromophores to surface functionalities. Advances in electronics and sensors have been made by decreasing the size of the components making electronics faster and sensors more sensitive and selective. These advances provide an important step in our ability to control size and thickness of insulating layers for modern electronic devices. The technique used to develop these films is to expose the surface, such as silicon, to a long chained molecule, and allow it to self assemble on the surface. The length of these chains can then be reduced to control the resistivity by reaction with electrons or ozone, and the pattern they make on the surface can be controlled by ion or electron bombardment using a mask or laser ablation by rastering the beam across the surface. Understanding and controlling the chemistry of these reactions is critical to make the next generation of devices.

- Building Polar Actinide Materials. Compounds that adopt polar structures are able to exhibit a wide range of important technological properties such as second-harmonic generation (nonlinear optics), piezoelectricity, and pyroelectricity. One strategy for constructing polar structures is to use oxoanions containing heavy atoms such as selenium, tellurium, and iodine. These oxoanions share a common feature: they contain a nonbonding pair of electrons that can be aligned during crystal formation to create polar structures. These anions have been combined with the actinide elements uranium, neptunium, and plutonium to create novel polar actinide materials. Some of the neptunium compounds are further unusual in that the distance between neptunium atoms within the crystals can be controlled, allowing magnetic interactions to take place between the actinide elements. This work allows detailed structure-property relationships to be developed in polar actinide materials. These relationships elucidate the properties of 5f electrons, which contribute uniquely to the bonding in actinide materials and provide models for polar materials of nonradioactive transition metals.

- Plutonium Oxide Unraveled. A collaboration of research groups has developed sophisticated quantum chemistry software to model the electronic properties of actinide materials. These computational programs solve the first-principles, basic equations governing the quantum mechanics of electrons and nuclei, to yield predictions about conducting properties, equilibrium structure, and other electronic properties of materials like plutonium oxide (PuO_2). In a recent series of calculations on a cluster of high-performance computers, it was predicted for the first time that PuO_2 is an insulating material with a band gap of a few eV and with ferro- and anti-ferromagnetic phases in close energetic balance. These results are consistent with subsequent experimental data obtained by other researchers. A successful description of electronic properties of PuO_2 is a prerequisite for more elaborated modeling of the interaction of PuO_2 surfaces with water and other environmental species. Understanding these basic processes is essential to predict the long-term stability of PuO_2 when it is exposed to air, water, and other common substances.

- Bioelectrochemistry on Nanostructured Surfaces. A defining feature of modern bioelectrochemistry is extraction of functional biomolecules and their reconstitution on patterned surfaces in defined geometries. The bioelectrochemical process of solar energy absorption and subsequent conversion of light energy uses two molecular reaction centers operating in series, Photosystems I (PSI) and II (PSII). Photon absorption triggers electron transfer reactions that generate an electric voltage. It is this electrochemical potential that is the source of free energy for conversion of light energy into chemical energy. It has been demonstrated for the first time that PSI molecules can be oriented by elementary dipole forces that exist at the air-water interface and the dipole points predominantly towards the water. Orientation was demonstrated by measurement of the magnitude and sign of the electrostatic potential above the PSI-containing air-water interface. Bioreaction centers supported in nanoporous media enable the construction of bioelectrochemical systems for both basic and applied needs.
- Thermophysical Properties of Macromolecular Systems in Nanoscopic Structures. An important part of nanotechnology is to understand whether the properties of polymeric systems in nanoscopic structures are different from those of the bulk. Theoretical studies have established for the first time that nanometer-length structures of polymer glasses exhibit a glass transition temperature which is significantly lower than that of the corresponding bulk polymer. These studies also established that the elastic properties of the polymer in such structures are considerably "weaker" than those of the bulk. Finally, and perhaps most importantly, it has been demonstrated that the elastic moduli of nanoscopic polymeric samples are highly anisotropic, raising serious concerns about the applicability of continuum-mechanics computational approaches for study of such systems. These predictions indicate that the mechanical stability of features smaller than 50 nm is severely degraded. Extrapolation of current technology as applied in the microelectronics industry might not be possible.
- Structure of Electric Double Layer at the Rutile Surface from Molecular Dynamics Simulations. Rutile (α-TiO_2) is the protective surface phase that will cover the drip shields over the waste canisters at the Yucca Mountain waste repository. It is also an important mineral in the chemical and materials industries as a catalytic substrate, photocatalyst, pigment, and ceramic raw material. Molecular simulation of the structure of the relaxed rutile (110) crystal surface in contact with aqueous solutions were performed to determine the structure of water molecules near the interface, adsorption of ions, identification of several modes of binding of adsorbed ions with surface oxygens, and static and dynamic properties of the surface. Quantitative experimental data provided by synchrotron x-ray investigations determined the distribution of adsorbed water molecules and cations at the rutile (110) surface and verified the predictive capabilities of the computational approaches. Computational chemical physics demonstrated the utility of classical models of the macroscopic properties of the electric double layer. Solid-liquid surface properties (colloidal

stability, structure of micelles, membranes, metallurgy, chemical sensors, catalysis, and synthesis of nanophase materials) can now be linked to the atomic-level structural information.

- Water-Driven Structural Transformation in Nanoparticles at Room Temperature. Natural mineralogical nanoparticles exist at ambient temperature, pressure, and humidity in the geosphere. Research on nanoparticulate mineral phases provides understanding of the role of natural nanoparticles and in predicting what the future of "new" nanoparticles will be in the environment. Zinc sulphide nanoparticles (~3nm, 700 atoms) synthesized in methanol exhibited a reversible structural transformation accompanying methanol desorbtion. The binding of water to the as-formed particles at room temperature led to a dramatic structural modification, significantly reducing distortions of the surface and interior to generate a structure close to that of the mineral sphalerite. This shows one route for post-synthesis control of nanoparticles structure, and the potential use of the nanoparticles' structural state as an environmental sensor. The results also demonstrate that the structure and reactivity of natural nanoparticles will depend both on the particle size and on the nature of the surrounding molecules.
- A Molecular Switch Controls Cell Identity. Like its fuzzy, dwarf namesake from the "Star Wars" movie, the YODA (YDA) mutant in Arabidopsis is small but powerful. Recent molecular genetic experiments reveal that YODA acts as a negative regulator of plant cell fate decisions following asymmetric cell divisions. This regulation is essential for establishing normal cell patterns for stomata, tiny surface pores in leaves and shoots. Pore size is regulated by a pair of flanking guard cells that serve as gas valves controlling carbon dioxide and water vapor movement in or out of the leaf. Early in development these cells make an irrevocable decision on whether they will end up as epidermal cells, or undergo an asymmetric division and become guard cells. YODA's kinase activity sends the signal that decides this developmental fate, thus determining the number of stomates on a leaf surface. So as plants grow and form new leaves, they can adjust to factors such as carbon dioxide, and water and light availability by changing stomatal density and distribution. This illustrates how protein-gene interactions within complex regulatory feedback loops and pathways can be deciphered to understand how a group of cells can grow, develop, and adapt to an ever-changing environment in the coordinated form of a whole plant.
- Structural and Functional Analysis of a Minimum Plant Centromere. Every chromosome, the carrier of hereditary information in all living organisms, contains three essential elements: the telomere ends, the origin of replication that initiates copying of genetic information, and the centromeres that direct the partitioning of chromosomes during cell division. Scientists have made a startling discovery about the nature of these centromeres in rice plants. Their sequencing of the centromere of rice chromosome 8 revealed the presence of four active, expressed genes. This discovery refutes long-held scientific beliefs that centromeres contained only structural information for chromosome segregation, programmed within vast stretches of "junk DNA" consisting of repetitive, rearranged and noncoding sequence tracts. This work, significant for being the first completely sequenced plant centromere, complements the international effort to complete the sequence of the rice genome, and represents the first step toward achieving such practical applications as the creation of artificial chromosomes for precision plant engineering.
- The Glass Bead Game of Molecular Detection. A significant challenge in the study of biological systems is the ability to detect molecular interactions with sensitivity and accuracy. Scientists have developed a novel technique for detecting substrate binding to proteins embedded within cellular membranes. Their technique uses the fundamental qualities of colloidal particles, which self-

assemble into a variety of ordered phases in a manner driven by the pair interaction potential between particles. Colloidal suspensions of membrane lipids linked to a specific substrate were coated onto silica beads. When a protein binds to this immobilized substrate, it causes small perturbations on the membrane surface that result in visible reorganization of the colloid, such that the coated beads disperse. The ability to sense molecular interactions without the use of expensive fluorescent probes has practical implications for rapid, high-throughput screening of a variety of interactions between biological molecules.

Selected FY 2004 Facility Accomplishments

- The Combustion Research Facility (CRF)
  - Sample Preparation Laboratory Ready for Advanced Microscopy. A laboratory has been converted to a sample preparation space for the research activities in the Advanced Microscopy Laboratory. The new lab is equipped with instrumentation and supplies for preparing ultra-clean samples critical to single molecule imaging of biomolecules and nanomaterials.
  - Optically Accessible Engine Facility Established. The facility's new automotive-scale Homogeneous-Charge Compression-Ignition (HCCI) engine provides versatile optical access, accommodating the study of combustion via a laser-based investigation of in-cylinder processes. The facility is well suited for the examination of advanced fuel-air mixture preparation strategies that have been proposed as a way of achieving the strong potential of HCCI engines.
  - New Instrument Developed to Investigate Complex Reaction Processes. A new instrument consisting of an ion- and laser-beam surface analysis system coupled to time-of-flight and high-resolution Fourier Transform ion cyclotron resonance mass spectrometers has been built and tested. The instrument is used to investigate complex spatiotemporal reaction processes related to the aging of materials and biological processes at the cellular level.
  - New Laser Diagnostics Measure Diesel Particulate Emissions. Laser-induced incandescence (LII) and Laser-Induced Desorption with Elastic Laser Scattering (LIDELS) are new diagnostic techniques that provide previously unobtainable time-resolved measurements critical for the optimization of engine performance. Real-time measurements are particularly crucial for the development of regeneration strategies for lean NO_x catalysts and diesel particulate filters.

Detailed Program Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Chemical Sciences, Geosciences, and Energy Biosciences Research	**207,886**	**227,465**	**210,290**
▪ **Atomic, Molecular, and Optical (AMO) Science**	**13,875**	**17,397**	**13,659**

This activity supports theory and experiments to understand the properties of and interactions among atoms, molecules, ions, electrons, and photons. Included among the research activities are studies to determine the quantum mechanical description of such properties and interactions; interactions of intense electromagnetic fields with atoms and molecules; development and application of novel x-ray light sources; and ultracold collisions and quantum condensates.

The knowledge and techniques developed in this activity have wide applicability. Results of this research provide new ways to use photons, electrons, and ions to probe matter in the gas and condensed phases. This has enhanced our ability to understand materials of all kinds and enables the full exploitation of the BES synchrotron light sources, electron beam micro-characterization centers, and neutron scattering facilities. Furthermore, by studying energy transfer within isolated molecules, AMO science provides the very foundation for understanding chemical reactivity, i.e., the process of energy transfer between molecules and ultimately the making and breaking of chemical bonds.

The AMO Science activity is the sole supporter of synchrotron-based AMO science studies in the U.S., which includes ultrashort x-ray pulse generation and utilization at the ALS and APS. This program is also the principal U.S. supporter of research in the properties and interactions of highly charged atomic ions, which are of direct consequence to fusion plasmas.

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

In FY 2006, major activities will include the interactions of atoms and molecules with intense laser pulses; the use of optical fields to control quantum mechanical processes; atomic and molecular interactions at ultracold temperatures; and the creation and utilization of quantum condensates that provide strong linkages between atomic and condensed matter physics at the nanoscale. A reduction of $3,738,000 in AMO science funding reflects a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research on the physics of highly charged ions and ultracold molecular systems.

	FY 2004	FY 2005	FY 2006
▪ **Chemical Physics Research**	**31,311**	**34,276**	**32,063**

This activity supports experimental and theoretical investigations of gas phase chemistry and chemistry at surfaces. Gas phase chemistry emphasizes the dynamics and rates of chemical reactions characteristic of combustion with the aim of developing theories and computational tools for use in combustion models and experimental tools for validating these models. The study of chemistry at well characterized surfaces and the reactions of metal and metal oxide clusters leads to the development of theories on the molecular origins of surface mediated catalysis.

This activity also has oversight for the Combustion Research Facility (which is budgeted below in Facilities Operations), a multi-investigator facility for the study of combustion science and technology. In-house BES-supported efforts combine theory, modeling, and experiment including diagnostic development, kinetics, and dynamics. Several innovative non-intrusive diagnostics have been developed to characterize gas-phase processes, including high-resolution optical spectroscopy, time-resolved Fourier transform infrared spectroscopy, picosecond laser-induced fluorescence, and ion-imaging. Other activities at the Combustion Research Facility involve BES interactions with Fossil Energy, Energy Efficiency and Renewable Energy, and industry.

This activity contributes significantly to DOE missions, since nearly 85% of the Nation's energy supply has its origins in combustion and this situation is likely to persist for the foreseeable future. The complexity of combustion — the interaction of fluid dynamics with hundreds of chemical reactions involving dozens of unstable chemical intermediates — has provided an impressive challenge to predictive modeling of combustion processes. Predicted and measured reaction rates will be used in models for the design of new combustion devices with maximum energy efficiency and minimum undesired environmental consequences.

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

The SciDAC computational chemistry program addresses three fundamental research efforts: (1) chemically reacting flows; (2) the chemistry of unstable species and large molecules; and (3) actinide chemistry. Each of these research efforts is carried out by a team of related scientists working with the appropriate Integrated Software Infrastructure Centers supported under SciDAC by the SC Advanced Scientific Computing Research program.

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

In FY 2006, there will be increased emphasis on chemical physics of condensed phase and interfacial chemistry, including the fundamental understanding of weak, non-covalent interactions and their relationship to chemical and physical properties of macroscopic systems. A reduction of $2,213,000 in chemical physics research reflects a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research in aspects of gas phase combustion chemistry.

	FY 2004	FY 2005	FY 2006
▪ **Photochemistry and Radiation Research**	**23,849**	**26,416**	**25,582**

This activity supports fundamental molecular level research on the capture and conversion of energy in the condensed phase. Fundamental research in solar photochemical energy conversion supports organic and inorganic photochemistry, photoinduced electron and energy transfer in the condensed phase, photoelectrochemistry, biophysical aspects of photosynthesis, and biomimetic assemblies for artificial photosynthesis. Fundamental research in radiation chemistry supports chemical effects produced by the absorption of energy from ionizing radiation. The radiation chemistry research encompasses heavy ion radiolysis, models for track structure and radiation damage, characterization of reactive intermediates, radiation yields, and radiation-induced chemistry at interfaces. Accelerator-based electron pulse radiolysis methods are employed in studies of highly reactive transient intermediates, and kinetics and mechanisms of chemical reactions in the liquid phase and at liquid/solid interfaces. This activity supports the Notre Dame Radiation Laboratory, a BES collaborative research center, emphasizing research in radiation chemistry.

Solar photochemical energy conversion is a long-range option for meeting future energy needs. An alternative to semiconductor photovoltaic cells, the attraction of solar photochemical and photoelectrochemical conversion is that fuels, chemicals and electricity may be produced with minimal environmental pollution and with closed renewable energy cycles. Artificial photosynthesis can be coupled to chemical reactions for generation of fuels such as hydrogen, methane, or complex hydrocarbons found in gasoline. The fundamental concepts devised for highly efficient excited-state charge separation in molecule-based biomimetic assemblies should also be applicable in the future development of molecular optoelectronic devices. A strong interface with EE solar conversion

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

programs exists at NREL, involving shared research, analytical and fabrication facilities, and involving a jointly shared project on dye-sensitized solar cells.

Radiation chemistry research supports fundamental chemical effects produced by the absorption of energy from ionizing radiation. This research is important for solving problems in environmental waste management and remediation, nuclear energy production, and medical diagnosis and radiation therapy. Fundamental studies on radiation-induced processes complement collocated Nuclear Energy Research Initiative (NERI) and the Environmental Management Science Program (EMSP) projects.

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

Capital equipment is provided for such items as pico- and femtosecond lasers, fast Fourier transform-infrared and Raman spectrometers, and upgrades for electron paramagnetic resonance spectroscopy.

In FY 2006, funding will include research to expand our knowledge of the semiconductor/liquid interface, colloidal semiconductors, and dye-sensitized solar cells; inorganic/organic donor-acceptor molecular assemblies and photocatalytic cycles; photosynthetic antennae and the reaction center; and radiolytic processes at interfaces, radiolytic intermediates in supercritical fluids, and characterization of excited states by dual pulse radiolysis/photolysis experiments. The overall decrease for photochemistry and radiation research is attributable to an increase for research related to the hydrogen economy ($+394,000) offset by a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease for research in radiation chemistry ($-1,228,000).

	FY 2004	FY 2005	FY 2006
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	**13,000**	**13,746**	**13,469**

This activity supports fundamental research to characterize the molecular mechanisms involved in the conversion of solar energy to biomass, biofuels, bioproducts, and other renewable energy resources. Research supported includes the characterization of the energy transfer processes occurring during photosynthesis, the kinetic and catalytic mechanisms of enzymes involved in the synthesis of methane, the biochemical mechanisms involved in the synthesis and degradation of lignocellulosics, and the mechanisms of plant oil production. The approaches used include biophysical, biochemical, and molecular genetic analyses. The goal is to enable the future biotechnological exploitation of these processes and, also, to provide insights and strategies into the design of non-biological processes. This activity also encourages fundamental research in the biological sciences that interfaces with other traditional disciplines in the physical sciences.

In FY 2006, funding will continue studies on understanding the constituents and molecular-level interactions within natural photosynthetic systems. Exploiting and mimicking components of natural solar energy conversion will enable future strategies for the bio-inspired design of new energy capture systems. The overall decrease is attributable to an increase for research related to the hydrogen economy ($+186,000) offset by a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research on aspects of electron transfer in photosynthesis ($-463,000).

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Metabolic Regulation of Energy Production**	**18,641**	**19,618**	**19,050**

This activity supports fundamental research in regulation of metabolic pathways and the integration of multiple pathways that constitute cellular function. The potential to synthesize an almost limitless variety of energy-rich organic compounds and polymers exists within the genetic diversity of plants and microbes. Understanding and realizing this potential is founded upon characterizing the genetic makeup of the organism and the regulation of these genes by physical and biological parameters. The research goal is to develop a predictive and experimental context for the manipulation and direction of metabolism to accumulate a desired product. Research supported includes the identification and characterization of genes and gene families within the context of metabolic pathways and their regulation by signaling pathways that can impact energy production; this includes understanding the transduction of signals received from physical sources (e.g. light, temperature, and solid surfaces) at the interface between the organism and its environment, as well as the transduction of signals received from biological sources (e.g. developmental programs, symbiotic or syntrophic relationships, and nutrient availability).

In FY 2006, funding will continue studies on Arabidopsis as a model system for the study of other plant systems with broader utility. Increased emphasis will be placed upon understanding interactions that occur within the nanoscale range; this includes signal reception at biological surfaces and membranes, catalytic and enzyme-substrate recognition, and how these molecules transfer within and between cellular components. This activity constitutes the fundamental biological advances needed to complement the chemical nanoscale catalysis activities. An emerging area will be the development of new imaging tools and methods to examine metabolic and signaling pathways and to visualize cellular architecture, at both the physical-spatial and temporal scale. In FY 2006, a reduction of $568,000 reflects a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a reduction in research on the use of microbes and yeasts to convert energy and produce alternative fuels.

▪ **Catalysis and Chemical Transformation**...........	**34,756**	**39,121**	**38,890**

This activity supports basic research to understand the chemical aspects of catalysis, both heterogeneous and homogeneous; the chemistry of fossil resources; and the chemistry of the molecules used to create advanced materials. This activity seeks to develop these principles to enable rational design of catalysts.

Catalytic transformations impact virtually all of the energy missions of the Department. Catalysts are needed for all of the processes required to convert crude petroleum into a clean burning fuel. The production of virtually every chemical-based consumer product requires catalysts. Catalysts are crucial to energy conservation in creating new, less-energy-demanding routes for the production of basic chemical feedstocks and value-added chemicals. Environmental impacts from catalytic science can include minimizing unwanted products from production streams and transforming toxic chemicals into benign ones, such as chlorofluorocarbons into environmentally acceptable refrigerants. Research supported by this program also provides the basis and impetus for creating a broad range of new materials, such as mesoporous solids which have improved catalytic properties.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

This activity is the Nation’s major supporter of catalysis research, and it is the only activity that treats catalysis as a discipline integrating all aspects of homogeneous and heterogeneous catalysis research.

Capital equipment is provided for such items as ultrahigh vacuum equipment with various probes of surface structure, Fourier-transform infrared instrumentation, and high-field, solid-state Nuclear Magnetic Resonance (NMR) spectrometers.

In FY 2006, funding will continue to address recommendations of the FY 2002 BESAC-sponsored workshop that described new opportunities afforded by progress in the tools and concepts of nanoscience. The availability of new tools for preparation, characterization, and analysis and the merging of concepts drawn from homogeneous (single phase such as solution) catalysis, heterogeneous (between phases such as gas-surface) catalysis, and biocatalysts provide the potential to pioneer new approaches to catalysis design. New strategies for the rational design of selective oxidation catalysts and catalysts for the production of hydrogen from renewable feedstocks will be explored, and the control of self assembled nanoscale catalyst structures will be studied. Innovative hybrid materials that integrate biomimetic approaches with advances in catalysis will be performed and the nature of biologically directed mineralization that results in exquisite structural control will be studied. Basic research into the chemistry of inorganic, organic, and inorganic/organic hybrid porous materials with pores in the 1-30 nm range will be undertaken, nano-scale self-assembly of these systems will be studied, and the integration of functional catalytic properties into nanomaterials will be explored. The overall decrease for catalysis and chemical transformations research is attributable to an increase for research related to the hydrogen economy ($+588,000) offset by a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research in thermochemical properties ($-819,000).

▪ **Separations and Analyses**	**14,029**	**16,680**	**15,897**

This activity supports fundamental research covering a broad spectrum of separation concepts, including membrane processes, extraction under both standard and supercritical conditions, adsorption, chromatography, photodissociation, and complexation. Also supported is work to improve the sensitivity, reliability, and productivity of analytical determinations and to develop entirely new approaches to analysis. This activity is the Nation’s most significant long-term investment in many aspects of separations and analysis, including solvent extraction, ion exchange, and mass spectrometry.

The goal of this activity is to obtain a thorough understanding of the basic chemical and physical principles involved in separations systems and analytical tools so that their utility can be realized.

Work is closely coupled to the Department’s stewardship responsibility for transuranic chemistry; therefore, separation and analysis of transuranic isotopes and their radioactive decay products are important components of the portfolio.

Knowledge of molecular level processes is required to characterize and treat extremely complex radioactive mixtures and to understand and predict the fate of associated contaminants in the environment. Though the cold war legacy is the most obvious of the Department’s missions, the economic importance of separation science and technology is huge. For example, distillation processes in the petroleum, chemical, and natural gas industries annually consume the equivalent of

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

315 million barrels of oil. It has been estimated that separation processes account for more than five percent of the total national energy consumption. Separations are essential to nearly all operations in the processing industries and are also necessary for many analytical procedures. An analysis is an essential component of every chemical process from manufacture through safety and risk assessment and environmental protection.

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

In FY 2006, funding will include studies at the nanoscale as well as the formation of macroscopic separation systems via self-assembly of nanoscale precursors. This work will build on recent advances in imaging single-molecule interactions and reactions and will expand our knowledge of how molecules interact with pore walls, with one another, and with other molecules to effect separation between molecules. Chemical analysis research will emphasize (1) the study of hydrogen-separation materials and processes under realistic environmental conditions, rather than in high vacuum; (2) achieve high temporal resolution, so that changes can be monitored dynamically; and (3) enable multiple analytical measurements to be made simultaneously on systems such as fuel cell membranes, which have three percolation networks (proton, electron, and gas). The overall decrease for separations and analysis is attributable to an increase for research related to the hydrogen economy ($+310,000) offset by a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in modeling of separation systems at the engineering level ($-1,093,000).

	FY 2004	FY 2005	FY 2006
▪ **Heavy Element Chemistry**	**10,359**	**9,912**	**9,547**

This activity supports research in actinide and fission product chemistry. Areas of interest include aqueous and non-aqueous coordination chemistry; solution and solid-state speciation and reactivity; measurement of chemical and physical properties; synthesis of actinide-containing materials; chemical properties of the heaviest actinide and transactinide elements; theoretical methods for the prediction of heavy element electronic and molecular structure and reactivity; and the relationship between the actinides, lanthanides, and transition metals.

The heavy element chemistry program, with its genesis in the Manhattan project, has explored the chemical properties of the transuranium and transactinide elements, the latter using techniques developed for isotopes that have half-lives on the order of seconds to tens of seconds. In recent years the emphasis of the program returned to the chemistry of the lighter transuranium elements and fission products, driven by the necessity to identify species found in the waste tanks at the Hanford and Savannah River sites. Knowledge of the molecular speciation of actinide and fission products materials under tank conditions is necessary to treat these complex mixtures. Accidental release of actinide and fission product materials to the environment also requires molecular speciation information in order to predict their fate under environmental conditions. This activity is closely coupled to the BES separations and analysis activity and to the actinide and fission product chemistry efforts in DOE's Environmental Science Program.

This activity represents the Nation's only funding for basic research in the chemical and physical principles governing actinide and fission product chemistry. The program is primarily based at the national laboratories because of the special licenses and facilities needed to obtain and safely handle radioactive materials. However, research in heavy element chemistry is supported at universities, and collaborations between university and laboratory programs are encouraged. The training of graduate students and postdoctoral research associates is viewed as an important responsibility of this activity. Approximately twenty undergraduate students chosen from universities and colleges throughout the U.S. are given introductory lectures in actinide and radiochemistry each summer.

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

In FY 2006, funding will continue to include experiment, theory, and modeling to understand the chemical bonding in the heavy elements. Experimental studies will include aqueous and non-aqueous high-pressure chemistry and surface chemistry of these elements. In addition, new beamlines at synchrotron light sources capable of handling samples of these heavy elements will permit detailed spectroscopic studies of specimens under a variety of conditions. The study of the bonding in these heavy elements may also provide new insights into organometallic chemistry, beyond that learned from "standard" organometallic chemistry based on transition metals with d-orbital bonding. A $365,000 decrease reflects a decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a reduction in activities in the role of transuranic elements on the properties of materials.

	FY 2004	FY 2005	FY 2006
▪ **Geosciences Research**	**21,356**	**22,599**	**20,423**

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

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

In FY 2006, funding will continue to provide the majority of individual investigator basic research funding for the federal government in areas with the greatest impact on unique DOE missions such as low-temperature, low-pressure geochemical processes in the subsurface. This activity provides the basic research component in solid Earth sciences to the DOE's energy resources and environmental quality portfolios. A reduction of $2,176,000 reflects a decrease due to one-time funding of research in geochemistry and geophysics and discontinued research in high resolution imaging of the earth's crust and the flow of fluids in porous media.

	FY 2004	FY 2005	FY 2006
▪ **Chemical Energy and Chemical Engineering**....	**10,837**	**10,492**	**4,244**

This activity supports research on electrochemistry, thermophysical and thermochemical properties, and physical and chemical rate processes. Also included is fundamental research in areas critical to understanding the underlying limitations in the performance of electrochemical energy storage and conversion systems including anode, cathode, and electrolyte systems and their interactions with

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

emphasis on improvements in performance and lifetime. The program covers a broad spectrum of research including fundamental studies of composite electrode structures; failure and degradation of active electrode materials; thin film electrodes, electrolytes, and interfaces; and experimental and theoretical aspects of phase equilibria, especially of mixtures, including supercritical phenomena.

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

In FY 2006, there will be reductions in research in the areas of physical properties related to process engineering, engineering approaches to electrochemical fuel cells, and aspects of advanced battery research ($-6,248,000).

	FY 2004	FY 2005	FY 2006
▪ **General Plant Projects (GPP)**..............................	**11,380**	**12,800**	**13,408**

GPP funding is increased in FY 2006 for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems principally at the Ames Laboratory, Argonne National Laboratory, and Oak Ridge National Laboratory as part of the BES stewardship responsibilities for these laboratories. Funding of this type is essential for maintaining the productivity and usefulness of the Department-owned facilities and in meeting requirements for safe and reliable facilities operation. Additional GPP funding is included in the Facilities Operations justification in both the Materials Sciences and Engineering subprogram and the Chemical Sciences, Geosciences, and Energy Biosciences subprogram. The total estimated cost of each GPP project will not exceed $5,000,000.

	FY 2004	FY 2005	FY 2006
▪ **General Purpose Equipment (GPE)**	**4,493**	**4,408**	**4,058**

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

	FY 2004	FY 2005	FY 2006
Facility Operations..	**5,892**	**6,169**	**6,169**

The facility operations budget request, which includes operating funds, capital equipment, and GPP is described in a consolidated manner later in this budget. This subprogram funds the Combustion Research Facility. GPP funding is also required for minor new construction, for other capital alterations and additions, and for improvements to land, buildings, and utility systems. The total estimated cost of each GPP project will not exceed $5,000,000.

Facilities

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Combustion Research Facility..	5,892	6,169	6,169

	FY 2004	FY 2005	FY 2006
	(dollars in thousands)		
SBIR/STTR	**0**	**5,841**	**5,342**

In FY 2004 $4,825,000 and $579,000 were transferred to the SBIR and STTR programs, respectively. The FY 2005 and FY 2006 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

	FY 2004	FY 2005	FY 2006
Total, Chemical Sciences, Geosciences, and Energy Biosciences	**213,778**	**239,475**	**221,801**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Chemical Sciences, Geosciences, and Energy Biosciences Research	
▪ **Atomic, Molecular, and Optical (AMO) Science**	
Decrease for atomic, molecular, and optical science because of a one-time funding increase in FY 2005 for all portfolio elements and a reduction for the physics of highly charged ions and ultracold molecular systems	-3,738
▪ **Chemical Physics Research**	
Decrease for chemical physics research because of a one-time funding increase in FY 2005 for all portfolio elements and a reduction in aspects of gas phase combustion chemistry	-2,213
▪ **Photochemistry and Radiation Research**	
Overall decrease for photochemistry and radiation research because of increase in research related to the hydrogen economy ($+394,000) and decrease due to a one-time funding increase in FY 2005 for all portfolio elements and a reduction for research in radiation chemistry ($-1,228,000)	-834
▪ **Molecular Mechanisms of Natural Solar Energy Conversion**	
Overall decrease in molecular mechanisms of natural solar energy conversion because of increase for research related to the hydrogen economy ($+186,000) and reduction due to a one-time funding increase in FY 2005 for all portfolio elements and a reduction for research in aspects of electron transfer related to photosynthesis ($-463,000)	-277
▪ **Metabolic Regulation of Energy Production**	
Decrease in metabolic regulation of energy production research due to a one-time funding increase in FY 2005 for all portfolio elements and a reduction in the area of production of alternate fuels by yeasts and microbes	-568

	FY 2006 vs. FY 2005 ($000)
▪ **Catalysis and Chemical Transformation**	
Overall decrease in catalysis and chemical transformations for research because of increase for research related to the hydrogen economy ($+588,000) and reduction due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research in thermochemical properties ($-819,000)	-231
▪ **Separations and Analyses**	
Overall decrease in separations and analyses because of increase for research related to the hydrogen economy ($+310,000) and reduction due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research for modeling systems at the engineering level ($-1,093,000)	-783
▪ **Heavy Element Chemistry**	
Decrease for heavy element chemistry due to a one-time funding increase in FY 2005 for all portfolio elements and a decrease in research on the role of transuranics on the properties of materials	-365
▪ **Geosciences Research**	
Decrease in geosciences research due to a one-time funding increase in FY 2005 for all portfolio elements and a reduction in the areas of high resolution imaging of the earth's crust and the flow of fluids in porous media	-2,176
▪ **Chemical Energy and Chemical Engineering**	
Decrease in chemistry and chemical engineering because of reduction in research in the areas of physical properties related to process engineering, engineering approaches to electrochemical fuel cells, and aspects of advanced battery research.	-6,248
▪ **General Plant Projects**	
Increase in general plant projects intended to help alleviate recurring maintenance costs by improving infrastructure ($+258,000) and an FY 2005 transfer between GPP and GPE ($+350,000)	+608
▪ **General Purpose Equipment**	
Decrease due to FY 2005 transfer between GPE and GPP	-350
SBIR/STTR	
Decrease in SBIR/STTR funding because of a decrease in operating expenses	-499
Total Funding Change, Chemical Sciences, Geosciences, and Energy Biosciences	**-17,674**

Construction

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Construction					
Spallation Neutron Source (ORNL)	123,865	79,891	41,744	-38,147	-47.7%
Project Engineering Design, Nanoscale Science Research Centers	2,982	1,996	0	-1,996	-100.0%
Project Engineering Design, Linac Coherent Light Source (SLAC)	7,456	19,914	2,544	-17,370	-87.2%
Linac Coherent Light Source (SLAC)	0	29,760	83,000	+53,240	+178.9%
Center for Functional Nanomaterials (BNL)	0	18,317	36,553	+18,236	+99.6%
The Molecular Foundry (LBNL)	34,794	31,828	9,606	-22,222	-69.8%
Center for Nanophase Materials Science (ORNL)	19,882	17,669	0	-17,669	-100.0%
Center for Integrated Nanotechnologies (SNL/LANL)	29,674	30,650	4,626	-26,024	-84.9%
Total, Construction	218,653	230,025	178,073	-51,952	-22.6%

Description

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

Benefits

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

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Spallation Neutron Source (SNS)**	**123,865**	**79,891**	**41,744**

The purpose of the SNS Project is to provide a next-generation short-pulse spallation neutron source for neutron scattering. The SNS will be used by researchers from academia, national and federal labs, and industry for basic and applied research and for technology development in the fields of condensed matter physics, materials sciences, magnetic materials, polymers and complex fluids, chemistry, biology, earth sciences, and engineering. When completed in 2006, the SNS will be significantly more powerful (by about a factor of 10) than the best spallation neutron source now in existence – ISIS at the Rutherford Laboratory in England. The facility will be used by 1,000-2,000 scientists and engineers annually. Interest in the scientific community in the SNS is increasing.

The SNS will consist of a linac-ring accelerator system that delivers short (microsecond) proton pulses to a target/moderator system where neutrons are produced by a process called spallation. The neutrons so produced are then used for neutron scattering experiments. Specially designed scientific instruments use these pulsed neutron beams for a wide variety of investigations. There will initially be one partially instrumented target station with the potential for adding more instruments and a second target station later.

The SNS project partnership among six DOE laboratories has taken advantage of specialized technical capabilities within the laboratories: Lawrence Berkeley National Laboratory in ion sources; Los Alamos National Laboratory in linear accelerators; Thomas Jefferson National Accelerator Facility in superconducting linear accelerators; Brookhaven National Laboratory in proton storage rings; Argonne National Laboratory in instruments; and Oak Ridge National Laboratory in targets and moderators.

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

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

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

Numerous conventional facilities, including the klystron, central utilities, and ring service buildings and the linac and ring tunnels, were advanced. Site utilities became available to support linac commissioning. In FY 2003, a Major Item of Equipment (MIE) was initiated for five SNS instruments: High-Pressure Diffractometer, High-Resolution Chopper Spectrometer, Single-Crystal Diffractometer, Disordered Materials Diffractometer, and Hybrid Polarized Beam Spectrometer. The MIE is funded at $7,387,000 in FY 2004, $7,643,000 in FY 2005, and $8,079,000 in FY 2006. These instruments will be built by individual DOE laboratories or consortia of DOE laboratories in collaboration with the SNS based on scientific merit and importance to users from universities, industries, and government laboratories.

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

FY 2005 budget authority was requested to continue R&D, procurement, and installation of equipment for instrument systems. Commissioning of Linac Systems will be completed. Commissioning of the high-energy beam transport and accumulator ring will begin; installation and testing for the ring-target beam transport system will be performed. Installation and testing will be performed and preparation for the read, mess review will start for target systems. The remaining major construction contracts will be completed. Procurement, installation, and testing will continue for integrated control systems.

FY 2006 budget authority is requested to complete the SNS Project. Procurement and installation of equipment for instrument systems will be performed. An accelerator readiness review will be completed and target systems will be commissioned. All requirements to begin operations will be met and all SNS facilities will be turned over to operations.

The estimated Total Project Cost remains constant at $1,411,700,000, and the construction schedule continues to call for project completion by mid-2006. Additional information on the SNS Project is provided in the SNS construction project data sheet, project number 99-E-334.

▪ **Project Engineering and Design, Nanoscale Science Research Centers**	**2,982**	**1,996**	**0**

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Project Engineering and Design, Linac Coherent Light Source**...	**7,456**	**19,914**	**2,544**

The purpose of the Linac Coherent Light Source (LCLS) Project is to provide laser-like radiation in the x-ray region of the spectrum that is 10 billion times greater in peak power and peak brightness than any existing coherent x-ray light source. This advance in brightness is similar to that of a synchrotron over a 1960's laboratory x-ray tube. Synchrotrons have revolutionized science across disciplines ranging from atomic physics to structural biology. Advances from the LCLS are expected to be equally dramatic. The LCLS Project would provide the world's first demonstration of an x-ray free-electron-laser (FEL) in the 1.5 - 15 Å range.

For many years, the Basic Energy Sciences Advisory Committee (BESAC) has been actively involved with the development of such a next-generation light source. In 1997, the BESAC report "DOE Synchrotron Radiation Sources and Science" recommended funding an R&D program in next-generation light sources. In 1999, the BESAC report "Novel, Coherent Light Sources" concluded, "Given currently available knowledge and limited funding resources, the hard x-ray region (8-20 keV or higher) is identified as the most exciting potential area for innovative science. DOE should pursue the development of coherent light source technology in the hard x-ray region as a priority. This technology will most likely take the form of a linac-based free electron laser using self-amplified stimulated emission or some form of seeded stimulated emission…"

The proposed LCLS will have properties vastly exceeding those of current x-ray sources in three key areas: peak brightness, coherence, and ultrashort pulses. The peak brightness of the LCLS is 10 billion times greater than current synchrotrons; the light is coherent or "laser like" enabling many new types of experiments; and the pulses are short (230 femtoseconds with planned improvements that will further reduce the pulse length to subfemtosecond levels) enabling studies of fast chemical and physical processes. The LCLS has considerable potential as a tool for groundbreaking research in the physical and life sciences. LCLS x-rays can be used to create and observe extreme conditions in matter, such as exotic excited states of atoms and warm dense plasmas, previously inaccessible to study. They can be used to directly observe changes in molecular and material structure on the natural time scales of atomic and molecular motions. LCLS x-rays offer an opportunity to image non-periodic molecular structures, such as single or small clusters of biomolecules or nanosctructured materials, at atomic or near-atomic resolution. These are only a few examples of breakthrough science that will be enabled by LCLS, planned to be the world's first "fourth generation" x-ray light source.

The LCLS project leverages capital investments in the existing SLAC linac as well as technologies developed for linear colliders and for the production of intense electron beams with radio-frequency photocathode guns. The SLAC linac will provide high-current, low-emittance 5–15 GeV electron bunches at a 120 Hz repetition rate. When traveling through a newly constructed long undulator, the electron bunches will lead to self-amplification of the emitted x-ray radiation, constituting the x-ray FEL. The availability of the SLAC linac for the LCLS Project creates a unique opportunity (worldwide) for demonstration and use of x-ray FEL radiation.

The proposed LCLS Project requires a 150 MeV injector to be built at Sector 20 of the 30-sector SLAC linac to create the electron beam required for the x-ray FEL. The last one third of the linac

	FY 2004	FY 2005	FY 2006

(dollars in thousands)

will be modified by adding two magnetic bunch compressors. Most of the linac and its infrastructure will remain unchanged. The existing components in the Final Focus Test Beam tunnel will be removed and replaced by a new 120 meter undulator and associated equipment.

FY 2006 Project Engineering Design (PED) funding of $2,544,000 is requested for Title I and Title II design work. Additional information on the LCLS Project is provided in the LCLS PED data sheet, project number 03-SC-002.

	FY 2004	FY 2005	FY 2006
▪ **Linac Coherent Light Source**	**0**	**29,760**	**83,000**

FY 2005 budget authority was requested to initiate long-lead procurements. Early acquisition of selected critical path items supported pivotal schedule and technical aspects of the project. These include acquisition of the 120 MeV injector linac, acquisition of the undulator modules and the measurement system needed for verification of undulator performance, and acquisition of main linac magnets and radiofrequency (RF) systems required to produce electron beams meeting the stringent requirements of the LCLS free-electron laser. The Total Estimated Cost (TEC) is $315,000,000 and the Total Project Cost is $379,000,000.

FY 2006 budget authority is requested to initiate physical construction of the LCLS conventional facilities including ground-breaking for the LCLS Near Experimental Hall, Undulator Hall, Beam Transfer Hall, connecting beam transfer tunnels, and the Central Laboratory and Office (CLO) building.

	FY 2004	FY 2005	FY 2006
▪ **Nanoscale Science Research Center – The Center for Functional Nanomaterials, Brookhaven National Laboratory**	**0**	**18,317**	**36,553**

The Center for Functional Nanomaterials (CFN), a BES Nanoscale Science Research Center, will have as its focus understanding the chemical and physical response of nanomaterials to make functional materials such as sensors, activators, and energy-conversion devices. The facility will use existing facilities such as the NSLS and the Laser Electron Accelerator facility. It will also provide clean rooms, general laboratories, and wet and dry laboratories for sample preparation, fabrication, and analysis. Equipment will include that needed for laboratory and fabrication facilities for e-beam lithography, transmission electron microscopy, scanning probes and surface characterization, material synthesis and fabrication, and spectroscopy.

FY 2006 funding is requested to continue construction of the Center for Functional Nanomaterials at Brookhaven National Laboratory. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information follows later in construction project data sheet 05-R-321.

	FY 2004	FY 2005	FY 2006
▪ **Nanoscale Science Research Center – The Molecular Foundry, LBNL**	**34,794**	**31,828**	**9,606**

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

physics, chemistry, biology, and molecular biology. State-of-the-art equipment will include clean rooms; controlled environmental rooms; scanning tunneling microscopes; atomic force microscopes; a transmission electron microscope; fluorescence microscopes; mass spectrometers; a DNA synthesizer and sequencer; a nuclear magnetic resonance spectrometer; ultrahigh vacuum scanning-probe microscopes; photo, uv, and e-beam lithography equipment; a peptide synthesizer; advanced preparative and analytical chromatographic equipment; and cell culture facilities.

FY 2004 funding was appropriated for the start of construction, FY 2005 funding continued construction and equipment procurement, and FY 2006 funding will complete construction. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information follows later in construction project data sheet 04-R-313.

▪ **Nanoscale Science Research Center – The Center for Nanophase Materials Sciences, ORNL**	**19,882**	**17,669**	**0**

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

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

▪ **Nanoscale Science Research Center – The Center for Integrated Nanotechnologies, Sandia National Laboratories/Los Alamos National Laboratory**	**29,674**	**30,650**	**4,626**

The Center for Integrated Nanotechnologies (CINT), a BES Nanoscale Science Research Center, will focus on exploring the path from scientific discovery to the integration of nanostructures into the micro- and macro-worlds. This path involves experimental and theoretical exploration of behavior, understanding new performance regimes and concepts, testing designs, and integrating nanoscale materials and structures. CINT focus areas are nanophotonics and nanoelectronics, complex functional nanomaterials, nanomechanics, and the nanoscale/bio/microscale interfaces. CINT will be jointly administered by Los Alamos National Laboratory and Sandia National Laboratories. This Center will make use of a wide range of specialized facilities including the Los Alamos Neutron Science Center and the National High Magnetic Field Laboratory at LANL.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

FY 2004, and FY 2005 funding was requested for the construction for the Center for Integrated Nanotechnologies managed jointly by Sandia National Laboratories and Los Alamos National Laboratory. FY 2006 funding is requested to complete this construction. Performance will be measured by meeting the cost and timetables within 10% of the baseline in the construction project data sheet. Additional information follows later in construction project data sheet 03-R-313.

Total, Construction	**218,653**	**230,025**	**178,073**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Spallation Neutron Source	
Decrease in funding for construction of the Spallation Neutron Source at ORNL, representing the scheduled ramp down of activities.	-38,147
Project Engineering and Design, Nanoscale Science Research Centers	
Decrease in Project Engineering and Design (PED) for Nanoscale Science Research Centers at ORNL, LBNL, SNL, and BNL, representing the scheduled change in PED funding profiles.	-1,996
Project Engineering and Design, Linac Coherent Light Source	
Decrease in funding for Project Engineering Design (PED) related to design-only activities for the Linac Coherent Light Source (LCLS) at SLAC, representing the scheduled decrease in activities.	-17,370
Linac Coherent Light Source	
Increase in funding to initiate construction for the LCLS project.	+53,240
Nanoscale Science Research Center – The Center for Functional Nanomaterials, Brookhaven National Laboratory	
Increase in funding for construction of the Center for Functional Nanomaterials at BNL.	+18,236
Nanoscale Science Research Center – The Molecular Foundry, LBNL	
Decrease in funding for construction of the Molecular Foundry at LBNL, representing the scheduled ramp down of activities.	-22,222

	FY 2006 vs. FY 2005 ($000)
▪ **Nanoscale Science Research Center – The Center for Nanophase Materials Sciences, ORNL**	
Decrease in funding for construction of the Center for Nanophase Materials Sciences at ORNL, representing the scheduled ramp down of activities....................	-17,669
▪ **Nanoscale Science Research Center – The Center for Integrated Nanotechnologies Sandia National Laboratories/Los Alamos National Laboratory**	
Decrease in funding for construction of the Center for Integrated Nanotechnologies at SNL/LANL, representing the scheduled ramp down of activities.	-26,024
Total Funding Change, Construction...	**-51,952**

Major User Facilities

Funding Schedule by Activity

Funding for the operation of these facilities is provided in the Materials Sciences and Engineering, and the Chemical Sciences, Geosciences, and Energy Biosciences subprograms.

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Major User Facilities					
Advanced Light Source at Lawrence Berkeley National Laboratory	43,937	45,600	42,367	-3,233	-7.1%
Advanced Photon Source at Argonne National Laboratory	95,740	99,950	98,000	-1,950	-2.0%
National Synchrotron Light Source at Brookhaven National Laboratory	37,398	37,400	37,400	0	0.0%
Stanford Synchrotron Radiation Laboratory at Stanford Linear Accelerator Center	29,670	30,654	28,300	-2,354	-7.7%
High Flux Isotope Reactor at Oak Ridge National Laboratory	40,284	46,930	40,032	-6,898	-14.7%
Radiochemical Engineering Development Center (REDC) at Oak Ridge National Laboratory	6,100	4,500	0	-4,500	-100.0%
Intense Pulsed Neutron Source at Argonne National Laboratory	16,768	17,055	17,055	0	0.0%
Manuel Lujan, Jr. Neutron Scattering Center at Los Alamos National Laboratory	9,844	10,053	10,300	+247	+2.5%
Spallation Neutron Source at Oak Ridge National Laboratory	18,397	33,100	106,872	+73,772	+222.9%
Combustion Research Facility at Sandia National Laboratories/California	5,892	6,169	6,169	0	0.0%
Center for Nanoscale Materials at Argonne National Laboratory	0	0	3,894	+3,894	—
Molecular Foundry at Lawrence Berkeley National Laboratory	0	0	8,554	+8,554	—
Center for Nanophase Materials Sciences at Oak Ridge National Laboratory	0	0	18,086	+18,086	—
Center for Integrated Nanotechnologies at Sandia National Laboratories/Albuquerque and Los Alamos National Laboratory	0	0	12,709	+12,709	—
Linac Coherent Light Source (LCLS) at Stanford Linear Accelerator Center	0	0	3,500	+3,500	—
Linac for LCLS	0	0	30,000	+30,000	—
Total, Major User Facilities	304,030	331,411	463,238	+131,827	+39.8%

Description

The BES scientific user facilities provide experimental capabilities that are beyond the scope of those found in laboratories of individual investigators. Synchrotron radiation light sources, high-flux neutron sources, electron beam microcharacterization centers, and other specialized facilities enable scientists to carry out experiments that could not be done elsewhere. These facilities are part of the Department's system of scientific user facilities, the largest of its kind in the world.

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	12,958	14,387	13,830	-557	-3.9%
Accelerator Improvement Projects	6,100	9,255	9,259	+4	+0.0%
Capital Equipment	83,795	87,993	99,362	+11,369	+12.9%
Total, Capital Operating Expenses	102,853	111,635	122,451	+10,816	+9.7%

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Unappro-priated Balances
05-R-320, SLAC, Linac Coherent Light Source	315,000[a]	0	0	29,760	83,000	166,240
05-R-321, BNL, Center for Functional Nanomaterials	79,700[b]	0	0	18,317	36,553	18,864
04-R-313, LBNL, The Molecular Foundry	83,700[c]	0	34,794	31,828	9,606	257
03-SC-002, PED, SLAC, Linac Coherent Light Source	36,000	5,925	7,456	19,914	2,544	161
03-R-312, ORNL, Center for Nanophase Materials Sciences	63,740[d]	23,701	19,882	17,669	0	0
03-R-313, SNL, Center for Integrated Nanotechnologies	73,800[e]	4,444	29,674	30,650	4,626	247
02-SC-002 PED, Nanoscale Science Research Centers	19,828	14,850	2,982	1,996	0	0
99-E-334, ORNL, Spallation Neutron Source	1,192,700	947,200	123,865	79,891	41,744	0
Total, Construction			218,653	230,025	178,073	185,769

[a] Includes $36,000,000 of PED included in the 03-SC-002 PED, SLAC, Linac Coherent Light Source datasheet.
[b] Includes $5,966,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[c] Includes $7,215,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[d] Includes $2,488,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.
[e] Includes $4,159,000 of PED included in the 02-SC-002 PED, Nanoscale Science Research Centers datasheet.

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Acceptance Date
ANL Center for Nanophase Materials	72,500[a]	36,000	0	10,000	12,000	14,000	FY 2006
SNS Instrumentation[b] ...	50–75,000	50–75,000	5,635	7,387	7,643	8,079	FY07–11 est.
Transmission Electron Aberration Corrected Microscope	25– 30,000	11,200–13,500	0	0	0	2,000	TBD
Total, Major Items of Equipment.....................				17,387	19,643	24,079	

[a] This includes $36,000,000 provided by the State of Illinois for construction of the building.
[b] This FY 2003 MIE includes five instruments: High-Pressure Diffractometer, High-Resolution Chopper Spectrometer, Single-Crystal Diffractometer, Disordered Materials Diffractometer, and Hybrid Polarized Beam Spectrometer.

Advanced Scientific Computing Research

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Advanced Scientific Computing Research					
Mathematical, Information, and Computational Sciences	193,879	234,340	-1,872[a]	232,468	207,055
Laboratory Technology Research	2,916	0	0	0	0
Total, Advanced Scientific Computing Research	196,795[b]	234,340	-1,872	232,468	207,055

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

Mission

The mission of the Advanced Scientific Computing Research (ASCR) program is to deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy. In the past two decades, leadership in scientific computation has become a cornerstone of the Department's strategy to ensure the security of the nation and succeed in its science, energy, environmental quality, and national security missions. According to a number of authorities, ranging from the President's Science Advisor and the President's Council of Advisors on Science and Technology to the National Research Council and the Council on Competitiveness, this scientific leadership should be a priority for the nation.

Benefits

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

[a] Reflects a rescission in accordance with P.L.108-447, the consolidated Appropriations Act, 2005.
[b] Includes a reduction of $1,198,000, for a rescission in accordance with P.L. 108-137, the consolidated Appropriations Act, 2004, a reduction of $4,908,000 which was transferred to the SBIR program, and a reduction of $589,000 which was transferred to the STTR program.

efficiency engines that could expand our economy, lower pollution, and reduce our dependence on foreign oil. Computational science is increasingly central to progress at the frontiers of almost every scientific discipline and to our most challenging feats of engineering.

Strategic and Program Goals

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

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

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

Program Goal 05.23.00.00: Deliver forefront computational and networking capabilities **—** Deliver forefront computational and networking capabilities to scientists nationwide that enable them to extend the frontiers of science, answering critical questions that range from the function of living cells to the power of fusion energy.

Contribution to Program Goal 05.23.00.00 (Deliver forefront computational and networking capabilities)

The ASCR program contributes to Program Goal 05.23.00.00 by delivering the fundamental mathematical and computer science research that enables the simulation and prediction of complex physical and biological systems, providing the advanced computing capabilities needed by researchers to take advantage of this understanding, and delivering the fundamental networking research and facilities that link scientists across the nation to the computing and experimental facilities and their colleagues to enable scientific discovery. ASCR supports fundamental research in applied mathematics, computer science, computer networks, and tools for electronic collaboration; integrates the results of these basic research efforts into tools and software that can be used by scientists in other disciplines, especially through efforts such as Scientific Discovery through Advanced Computing (SciDAC); and provides the advanced computing and network resources that enable scientists to use these tools to deliver extraordinary science. Applied Mathematics enables scientists to build models of physical and natural systems with extraordinary fidelity, and provides the algorithms the computer requires to manipulate that representation of the world effectively, exposing the underlying structure. Computer science research provides the link between the mathematics and the actual computer systems. Finally, scientific discovery results from simulations conducted on the advanced computers themselves, including experimental computers with hardware designs optimized to enable particular types of scientific applications, and the largest computing capabilities available to the general scientific community. All of these elements are critical to advance the frontiers of simulation. Shrinking the distance between scientists and the resources they need is also critical to the 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 General Goal 5 by enabling research programs across SC, as well as other elements of the Department, to succeed. The following indicators establish specific long term (10 years) goals in Scientific Advancement that the ASCR program is committed to, and progress can be measured against:

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

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 05.23.00.00 Deliver forefront computational and networking capabilities					
Mathematical, Information and Computational Sciences					
		Completed the definitive analysis of the advantages and issues associated with lightweight kernel operating systems rather than full kernels for the compute nodes of extreme-scale scientific computers, resolving a critical issue for the future of high performance computers in the U.S. [Goal Met]			
		Began installation of next generation National Energy Research Scientific Computing Center (NERSC) computer, NERSC-4, that will at least double the capability available in FY 2002 to solve leading edge scientific problems. [Goal Not Met]	Maintained Procurement Baselines. Percentages within (1) original baseline cost for completed procurements of major computer systems or network services, and (2) original performance baseline versus integrated performance over the life of the contracts. [Goal Met]	Maintain 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. FY 2005 — <10%	Maintain 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. FY 2006 — <10%
		Initiated at least 5 competitively selected interdisciplinary research teams to provide computational science and applied mathematics advances that will accelerate biological discovery in microbial systems and develop the next generation of computational tools required for nanoscale science based on peer review, in partnership with the Biological and Environmental Research (BER) and Basic Energy Sciences (BES) programs, respectively, of submitted proposals. [Goal Met]	*Improved Computational Science Capabilities. Average annual percentage increased in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. [Goal Met]*	*Improve Computational Science Capabilities. Average annual percentage increase in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2005 — >50%*	*Improve Computational Science Capabilities. Average annual percentage increase in the computational effectiveness (either by simulating the same problem in less time or simulating a larger problem in the same time) of a subset of application codes within the SciDAC effort. FY 2006 — >50%*

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
		Maintained and operated facilities, including NERSC and ESnet, so the unscheduled downtime on average is less than 10% of the total scheduled operating time. [Goal Met]	Focused usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used was accounted for by computations that required at least 1/8 of the total resource. [Goal Not Met]	Focus usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that is accounted for by computations that require at least 1/8 of the total resource. FY 2005 — 40%	Focus usage of the primary supercomputer at the NERSC on capability computing. Percentage of the computing time used that is accounted for by computations that require at least 1/8 of the total resource. FY 2006 — 40%
Initiated project to understand the advantages and issues associated with lightweight kernel operating systems rather than full kernels for the compute nodes of extreme-scale scientific computers. [Goal Met]	Completed the development of the Cougar lightweight kernel for clusters of Alpha processor-based computers and began the assessment of scalability and performance for selected applications. [Goal Met]				
Continued to fabricate, assemble, and operate premier supercomputer and networking facilities that served researchers at national laboratories, universities and within industry, enabling understanding of complex problems and effective integration of geographically distributed teams in national collaborations. [Goal Met]	Achieved operation of the IBM-SP computer at 5.0 teraflop "peak" performance. These computational resources were integrated by a common high performance file storage system that facilitates interdisciplinary collaborations. Transferred the users with largest data processing and storage needs to the IBM-SP from the previous generation Cray T3E. [Goal Met]				

Means and Strategies

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

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

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

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

Validation and Verification

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

Program Assessment Rating Tool (PART)

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 2006 Budget Request and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the ASCR program a relatively high score of 84% overall which corresponds to a rating of "Moderately Effective." OMB found that the program supports world-class scientific user facilities, has demonstrated an improved level of interagency communication and cooperation, is in the process of drafting a long-term strategic vision, and has been very successful with a major effort in interdisciplinary software. The assessment found that ASCR has developed a limited number of adequate performance measures which are continued for FY 2006. These measures have been incorporated into this budget request, ASCR grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance-based contracts of Management and Operating (M&O) contractors. To better explain these complex scientific measures, SC has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Advanced Scientific Computing Advisory Committee (ASCAC) and also available on the website, will guide reviews every three years by ASCAC of progress toward achieving the long-term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report. In response to PART findings, ASCR established a 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 has received the report from the COV and is working on an action plan to respond to the recommendations. In addition, the ASCR strategic plan was approved by the Director, Office of Science, on August 19, 2004. All of these efforts enable ASCR to implement the OMB criteria for basic research programs.

ASCR's role in providing scientific research facilities is strongly supported by the Administration. Funding is provided in FY 2006 to operate the program's facilities at maximum capacity.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.23.00.00, Deliver forefront computational and networking capabilities			
Mathematical, Information and Computational Sciences	193,879	232,468	207,055
Laboratory Technology Research	2,916	0	0
Total, General Goal 05, World-Class Scientific Research Capacity	196,795	232,468	207,055

Overview

Computational modeling and simulation are among the most significant developments in the practice of scientific inquiry in the 20th Century. Scientific computing is particularly important for the solution of research problems that are insoluble by traditional theoretical and experimental approaches, hazardous to study in the laboratory, or time-consuming or expensive to solve by traditional means. All of the SC research programs—Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, and Nuclear Physics—have identified major scientific challenges that can only be addressed through advances in scientific computing.

ASCR research underpins the efforts of the other programs in SC. The applied mathematics research activity produces the fundamental mathematical methods to model complex physical and biological systems. The computer science research efforts enable scientists to efficiently perform scientific computations on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. The networking research activity provides the techniques to link the data producers (e.g., supercomputers and large experimental facilities) with scientists who need access to the data.

ASCR's other principal responsibility is to provide the high-performance computational and networking resources that are required for world leadership in science. Recent dramatic advances in scientific computation by researchers and computer companies underscore the importance of strengthening our position in computational sciences in strategic areas. In March 2002, Japan's NEC Earth Simulator became operational. With a peak speed of 40 teraflops and a demonstrated sustained capability of over 25 teraflops, it is faster by approximately a factor of 50 than the most advanced supercomputer for civilian science—through not for national security work—in the United States. The Administration has recognized the importance of high-end computing. As stated in the "Analytical Perspectives" of the FY 2004 Budget:

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

To address these issues the President's Science Advisor chartered the High End Computing Revitalization Task Force (HECRTF), which developed a plan for a Federal research program to address these issues. This task force was co-chaired by SC and the Department of Defense (DOD). The Next Generation Architecture (NGA) activity, begun by ASCR in FY 2004, is one of the key foundations for this effort.

How We Work

The ASCR program uses a variety of mechanisms for conducting, coordinating, and funding research in applied mathematics, network and computer sciences, and in advanced computing software tools. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting core university and national laboratory programs, and maintaining a strong infrastructure to support research in applied mathematics, network and computer science, and advanced computing software tools. The quality of the research supported by the ASCR program is continuously evaluated through the use of merit-based peer review, scientific advisory committees, and interagency coordinating bodies.

Advisory and Consultative Activities

The Advanced Scientific Computing Advisory Committee (ASCAC) provides valuable, independent advice to DOE on a variety of complex scientific and technical issues related to the ASCR program. The ASCAC is charged with providing advice on promising future directions for advanced scientific computing research; strategies to couple advanced scientific computing research to other disciplines; and the relationship of the DOE program to other Federal investments in information technology (IT) research. ASCAC's recommendations include advice on long-range plans, priorities, and strategies to address more effectively the scientific aspects of advanced scientific computing including the relationship of advanced scientific computing to other scientific disciplines, and maintaining appropriate balance among elements of the program. This advisory committee plays a key role in assessing the scientific and programmatic merit of presently funded activities and in evaluating plans for the future. The Committee formally reports to the SC Director and includes representatives from universities, national laboratories, and industries who are involved in advanced computing research. Particular attention is paid to obtaining a diverse membership with a balance among scientific disciplines, institutions, and geographic regions. ASCAC operates in accordance with the Federal Advisory Committee Act (FACA), Public Law 92-463; 92nd Congress, H.R. 4383, October 6, 1972, and all applicable FACA Amendments, Federal Regulations, and Executive Orders.

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

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

- Blueprint for Future Science Middleware and Grid Research and Infrastructure, August 2002 (http://www.nsf-middleware.org/MAGIC/default.htm);
- DOE Science Network Meeting, June 2003 (http://gate.hep.anl.gov/may/ScienceNetworkingWorkshop/);
- DOE Science Computing Conference, June 2003 (http://www.doe-sci-comp.info);
- Science Case for Large Scale Simulation, June 2003 (http://www.pnl.gov/scales/);
- Workshop on the Road Map for the Revitalization of High End Computing (http://www.cra.org/Activities/workshops/nitrd/);
- Cyber infrastructure Report (http://www.cise.nsf.gov/sci/reports/toc.cfm); and
- ASCR Strategic Planning Workshop (http://www.fp-mcs.anl.gov/ascr-july03spw).

Finally, in FY 2003 and FY 2004, ASCR participated in the HECRTF government-wide planning activity, which was established by the President's Science Advisor under the NSTC. The resulting "Federal Plan for High-End Computing, report of the High End-Computing Revitalization Task Force (HECRTF)" (http://www.itrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf), which was released on April 13, 2004, plays a critical role in ASCR planning. This plan will be referred to as the "HECRTF Plan."

Facility Operations Reviews

The ASCR program has undertaken a series of operations reviews of the National Energy Research Scientific Computing Center (NERSC), the Energy Sciences Network (ESnet), and the Advanced Computing Research Testbeds (ACRTs).

NERSC, operated by the Lawrence Berkeley National Laboratory (LBNL), annually serves about 2,000 scientists throughout the United States. These researchers work at DOE laboratories, universities, industrial laboratories, and other Federal agencies. Allocations of computer time and archival storage at NERSC are awarded to research groups based on a review of submitted proposals. As proposals are submitted, they are subjected to peer review to evaluate the quality of science, the relevance of the proposed research to SC goals and objectives, and the readiness of the proposed application to fully utilize the computing resources being requested.

The ESnet, managed and operated by the LBNL, is a high-speed network serving thousands of DOE scientists and collaborators worldwide. A pioneer in providing DOE mission-oriented high-bandwidth, reliable connections, ESnet enables researchers at national laboratories, universities, and other institutions to communicate with each other using the leading edge collaborative capabilities, not available in the commercial world, that are needed to address some of the world's most important scientific challenges. The ESnet Steering Committee (ESSC) was established in 1985 to ensure that ESnet meets the needs of SC programs. All program offices in SC appoint members, who represent their scientific communities, to serve on the ESSC. The ESSC is responsible for reviewing and prioritizing network requirements, for establishing performance objectives, and for proposing innovative techniques for enhancing ESnet capabilities. In addition to the ongoing oversight from the ESSC, ASCR conducts external peer reviews of ESnet performance on a three year interval. The last such review was chaired by a member of ASCAC and took place in September 2001. The next review is planned for Spring of 2005.

ACRTs play a critical role in testing and evaluating new computing hardware and software. These evaluations are called Research & Evaluation (R&E) prototypes in the HECRTF Plan. Current R&E prototypes are located at the Oak Ridge National Laboratory's (ORNL's) Center for Computational Sciences (CCS) (Cray X1 Technology and SGI large shared memory technology). In FY 2002, ASCAC conducted a review of NERSC and the ACRTs. The charge to ASCAC, posed the following questions:

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

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

In FY 2001, ASCR conducted a peer review of the CCS at ORNL. The findings from this review validated the contributions that the CCS made to the ACRT activity within the ASCR program. In FY 2004, ASCR conducted a peer review of the CCS evaluation of the Cray X1 computer. The results from this review validated the exceptionally effective results of the evaluation and its contributions to the Federal high performance computing effort. Also in FY 2004, ASCR conducted a peer reviewed competition to establish a Leadership Class Computing facility for Open Science. This competition was won by a partnership of ORNL's CCS with Argonne National Laboratory (ANL) and Pacific Northwest National Laboratory (PNNL) that located the Leadership Class Facility at the CCS.

Program Reviews

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

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

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

In FY 2002, following a comprehensive peer review, the ASCR program approved a proposal from the LBNL to manage and operate the NERSC for FY 2002–FY 2006.

Planning and Priority Setting

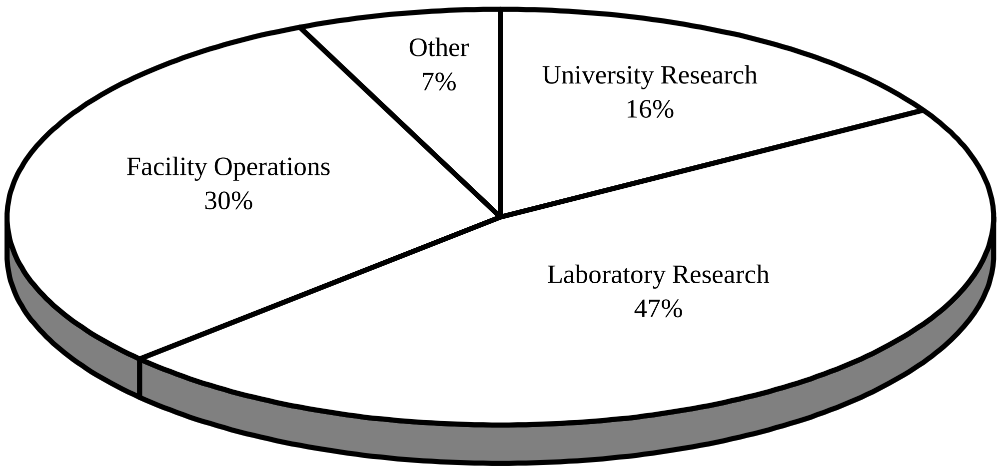
The ASCR program must coordinate and prioritize a large number of goals from agency and interagency strategic plans. One of the most important activities of ASCAC is the development of a framework for the coordinated advancement and application of network and computer science and applied mathematics. This framework must be sufficiently flexible to rapidly respond to developments in a fast paced area of research. The key planning elements for this program are:

- The Department and SC Strategic Plan, as updated through program collaborations and joint advisory committee meetings. (http://www.sc.doe.gov/Sub/Mission/mission_strategic.htm);
- SciDAC plan delivered to Congress in March 2000. (http://www.science.doe.gov/scidac/);
- ASCAC report on the Japanese Earth Simulator. (http://www.sc.doe.gov/ascr/ascac_reports.htm);
- The HECRTF Plan (http://www.itrd.gov/pubs/2004_hecrtf/20040702_hecrtf.pdf)

How We Spend Our Budget

The ASCR program budget has two subprograms: Mathematical, Information and Computational Sciences (MICS) and Laboratory Technology Research (LTR). The MICS subprogram has two major components: research and facility operations. The FY 2006 budget request continues the core and SciDAC research efforts and strengthens the research partnerships with other SC offices. Network operations expenditures account for 22% of the national laboratory research. The LTR subprogram was brought to a successful completion in FY 2004.

Advanced Scientific Computing Research Budget Allocation
FY 2006



Research

63 percent of the ASCR program's FY 2006 funding will be provided to scientists at universities and laboratories to conceive and carry out their research. National laboratory research scientists work together with the other programs of SC to develop the tools and techniques that allow those programs to take advantage of terascale computing for scientific research. The laboratories provide state-of-the-art resources for testbeds and novel applications. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. During FY 2004, the ASCR program supported over 150 grants to the nation's university researchers and graduate students engaged in civilian applied mathematics, large-scale network and computer science research. In addition, ASCR supports a Computational Science Graduate Fellowship and an Early Career Principal Investigator activity in Applied Mathematics, Computer Science and High-Performance Networks. In FY 2004, ASCR selected 24 new graduate students representing 17 universities and 13 states, and made 29 awards to early career principal investigators. Approximately half of those who received Ph.D.'s in the Computational Sciences Graduate Fellowship program between 1991 and 2001 are pursuing careers outside universities or national labs. ASCR also provides support to other SC research programs.

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

- ***National Laboratory Research***: ASCR supports national laboratory-based research groups at Argonne, Brookhaven, Los Alamos, Lawrence Berkeley, Lawrence Livermore, Oak Ridge, Pacific Northwest, and Sandia national laboratories and Ames Laboratory. The directions of laboratory research programs are driven by the needs of the Department and the unique capabilities of the laboratories to support large scale, multidisciplinary, collaborative research activities. In addition, laboratory-based research groups are highly tailored to the major scientific programs at the individual laboratories and the computational research needs of SC. Laboratory researchers collaborate with other laboratory and academic researchers, and are important for developing and maintaining testbeds and novel applications of high performance computing and networking in SC research. At Los Alamos, Livermore, and Sandia, ASCR funding plays an important role in supporting basic research that can improve the applied programs, such as the Accelerated Strategic Computing Initiative (ASCI) and the Science-Based Stockpile Stewardship program.

ASCR funds field work proposals from the national laboratories. Proposals are reviewed by external scientific peers and awarded using procedures that are equivalent to the 10 CFR 605 guidelines used for the grants program. Performance of the laboratory groups is reviewed by ASCR staff annually to examine the quality of their research and identify needed changes, corrective actions or redirection of effort. Individual laboratory groups have special capabilities or access to laboratory resources that can be profitably utilized in the development of the research program.

Significant Program Shifts

The ASCR program advances mathematics and computer science, and develops the specialized algorithms, the scientific software tools, and the software libraries needed by DOE researchers to effectively use high-performance computing and networking hardware for scientific discovery. The ASCR program has been a leader in the computational sciences for several decades and has been acknowledged for pioneering accomplishments. The FY 2006 ASCR budget is focused in priority areas identified by the Joint OMB-Office of Science and Technology Policy (OSTP) Research Priorities memorandum issued in August 2004.

Major elements of the ASCR portfolio related to SciDAC will be recompeted in FY 2006, with attention paid to support for the long term maintenance and support of software tools such as mathematical libraries, adaptive mesh refinement software, and scientific data management tools developed in the first 5 years of the effort. In addition, in FY 2006 ASCR is changing the way in which it manages its Genomics: GTL partnership with BER. The management of these efforts will be integrated into the portfolio of successful SciDAC partnerships. Finally, in FY 2006 ASCR will initiate a small number of competitively selected SciDAC institutes at universities which can become centers of excellence in high end computational science in areas that are critical to DOE missions at a total funding level of $8,000,000.

The research effort in Collaboratory Tools and Pilots and Networking will be restructured into an integrated Distributed Network Environment activity focused on basic research in computer networks and the middleware needed to make these networks tools for science. This change will enable the reduced NGA effort to operate computers, such as the 20 teraflop Cray X1e and Cray Red Storm system acquired in FY 2004 and FY 2005 at the ORNL-CCS, as tools for science and especially to satisfy the demand for resources that has resulted from the successful SciDAC efforts. In addition, the NGA activity will initiate a new competition for Research and Evaluation Prototype Computer testbeds to enable SciDAC teams to evaluate the potential of future architectures. NGA will continue its focus on research in operating systems and systems software.

The National Leadership Computing Facility acquired under the NGA Leadership Class Competition in FY 2004, will be operated to provide high performance production capability to selected SC researchers. The NGA efforts, as well as the enhancement of NERSC are aligned with the plan developed by the HECRTF established by the National Science and Technology Council (NSTC) and OSTP. These efforts will play a critical role in enabling Leadership Class Machines that could lead to solutions for scientific and industrial problems beyond what would be attainable through a continued simple extrapolation of current computational capabilities. This area has been identified as a priority within the overall Networking and Information Technology Research and Development (NITR&D) priorities of the Administration.

The FY 2006 budget request includes $7,500,000 for continued support of the Genomics: GTL research program, in partnership with the BER program; $2,600,000 for the Nanoscale Science, Engineering and Technology initiative led by the BES program; and $1,350,000 for support of the Fusion Simulation Project, led by the Fusion Energy Sciences program. ASCR's contributions to these partnerships will consist of advancing the mathematics and developing new mathematical algorithms to simulate biological systems and physical systems at the nanoscale. These partnerships support the Biology of Complex Systems and National Nanotechnology Initiative priorities identified by OSTP and OMB.

The FY 2006 budget also includes $8,500,000 to continue the "Atomic to Macroscopic Mathematics" (AMM) research support in applied mathematics needed to break through the current barriers in our understanding of complex physics processes that occur on a wide range of interacting length- and time-scales. Achieving this basic mathematical understanding will provide enabling technology to virtually every challenging computational problem faced by SC.

In FY 2006, the MICS subprogram will continue to support core research activities in applied mathematics, computer science, and network research.

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

The Laboratory Technology Research subprogram was brought to a successful conclusion in FY 2004 as planned with orderly completion of all existing Cooperative Research and Development Agreements (CRADAs). This does not mean that technology transfer activities have ended; rather, these activities are now institutionalized as a part of the process of doing research at DOE sites.

Interagency Environment

The activities funded by the MICS subprogram are coordinated with other Federal efforts through the Interagency Principals Group, chaired by the President's Science Advisor, and the Information Technology Working Group (ITWG). The ITWG evolved through an interagency coordination process that began under the 1991 High Performance Computing Act as the High Performance Computing, Communications, and Information Technology (HPCCIT) Committee. DOE has been an active participant in these coordination groups and committees since their inception. The MICS subprogram will continue to coordinate its activities through these mechanisms and will lead the development of new coordinating mechanisms as needs arise. The DOE program solves mission critical problems in scientific computing. In addition, results from the DOE program benefit the Nation's information technology basic research effort. The FY 2006 program positions DOE to make additional contributions to this effort. In the area of high performance computing and computation, ASCR has extensive partnerships with other Federal agencies and the NNSA. Examples include: participating in the program review team for the DARPA High Productivity Computing Systems program; serving on the planning group for the Congressionally mandated DOD plan for high performance computing to serve the national security mission; serving on the OSTP High End Computing Revitalization Task Force; and extensive collaboration with NNSA-Advanced Simulation Computing. In FY 2003, ASCR formalized many of these interactions by developing a Memorandum of Understanding with SC, NNSA, DOD's Under Secretary for Defense Research and Engineering, DARPA, and the National Security Administration to coordinate research, development, testing, and evaluation of high performance computers.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC mission areas with the goal of achieving breakthrough scientific advances via computer simulation that were impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit terascale computing and networking resources. The program is bringing computation and simulation to parity with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate modeling and prediction, plasma physics, particle physics, accelerator design, astrophysics, chemically reacting flows, and computational nanoscience.

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

In FY 2006, ASCR is reducing SciDAC efforts in collaboratories as it restructures and integrates collaboratory research and network research into an integrated effort to develop the middleware and underlying network capabilities needed for the science of the 21st century. The DOE collaboratory research and pilot projects have developed software that enables scientists across the world to access DOE facilities and work together to address critical scientific questions. This software is a critical part of plans in High Energy Physics to access data from the Large Hadron Collider in Switzerland. However, the funds that the reduction in these efforts makes available are needed to enable ASCR to provide adequate high performance computing resources that are critical for SciDAC teams to achieve their full potential. In addition, in FY 2006 ASCR will initiate a small number of competitively selected SciDAC institutes at Universities which can become centers of excellence in high end computational science in areas that are critical to DOE missions at a total funding level of $8,000,000.

Next Generation Computer Architecture for Science and Industry

The Next Generation Computer Architecture for Science and Industry (NGA) research activity is an integral part of an SC strategy to acquire additional advanced computing capability to support existing users in the near-term and to initiate longer-term research and development on next generation computer architectures. The goal of the NGA is to identify and address major architectural bottlenecks in the performance of existing and planned DOE science applications, such as internal data movement in very large systems. In FY 2006, the NGA effort will support computer science research that supports high performance computers such as operating systems that scale to tens of thousands of processors and techniques for evaluating the potential performance of novel computer architectures, operation of high performance computers at ORNL's Center for Computational Sciences, and a new competitive program to select R&E Prototype computer testbeds at multiple locations. The computers at the CCS will enable significant scientific progress by delivering significant increases in performance to critical DOE mission applications; and will also enable industrial researchers to find opportunities for virtual prototypes and simulation of industrial processes that result in an enhanced competitive position because of sharply reduced 'time to market'.

The new R&E Prototype testbeds will enable SciDAC teams and other leading edge computational scientists to evaluate the potential of new computer architectures as tools for science.

The NGA activity is coordinated with other Federal agencies to gain additional insight into research directions, optimize the utilization of resources, and establish the framework for a national effort. In May 2004, the Administration issued the report of the HECRTF, titled "Federal Plan for High-End Computing," which specifically cites DOE's NGA activity. The Plan emphasizes a coordinated, sustained research program for high-end computing and an interagency collaborative strategy for addressing mission agency needs for additional computational resources. SC has a prominent role throughout this plan, and the NGA effort is fully aligned with the plan.

Scientific Facilities Utilization

The ASCR program's FY 2006 request includes support to the NERSC, ESnet, and Center for Computational Sciences (CCS), components of SC-wide Facilities Optimization effort. The investment in NERSC will provide computer resources for about 2,000 scientists in universities, DOE laboratories, Federal agencies, and U.S. companies. The proposed funding will enable NERSC to maintain its role as one of the Nation's premier unclassified computing centers, a critical element for success of many SC research programs. The investment in ESnet will provide the DOE science community with capabilities not available through commercial networks or the commercial Internet. ESnet provides national and international high-speed access to DOE and SC researchers and research facilities, including light sources, neutron sources, particle accelerators, fusion reactors, spectrometers, supercomputers, and other high impact scientific instruments. The investment in the CCS will provide operation of the Leadership Class Computing Capability for Science.

	FY 2004	FY 2005 Est.	FY 2006 Est.
NERSC			
Maximum Hours	8,760	8,760	8,760
Scheduled Hours	8,585	8,585	8,585
Unscheduled Downtime	1%	1%	1%
ESnet			
Maximum Hours	8,760	8,760	8,760
Scheduled Hours	8,585	8,585	8,585
Unscheduled Downtime	1%	1%	1%
CCS			
Maximum Hours	7,008	7,008	7,008
Scheduled Hours	7,008	7,008	7,008
Unscheduled Downtime	1%	1%	1%

Workforce Development

The R&D Workforce Development mission is to ensure the supply of computational and computer science Ph.D. level scientists for the Department and the Nation through graduate student and postdoctoral research support. In FY 2006, this program will support approximately 800 graduate students and post doctoral investigators, of which 500 will be supported at SC user facilities.

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

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	140	142	135
Average Size/Duration	$197,000/yr-3yrs	$197,000/yr-3yrs	$197,000/yr-3yrs
# Laboratory Groups	165	165	155
# Graduate Students (FTEs)	354	354	350
# Permanent Ph.D.s (FTEs)	675	675	625

Mathematical, Information, and Computational Sciences

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Mathematical, Information, and Computational Sciences					
Mathematical, Computational, and Computer Sciences and Distributed Network Environment Research	97,912	102,575	107,026	+4,451	+4.3%
High Performance Computing and Network Facilities and Testbeds	95,967	123,608	94,400	-29,208	-23.6%
SBIR/STTR	0	6,285	5,629	-656	-10.4%
Total, Mathematical, Information, and Computational Sciences	193,879	232,468	207,055	-25,413	-10.9%

Description

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

Benefits

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

- What new mathematics are required to effectively model systems such as the earth's climate or the behavior of living cells that involve processes taking place on vastly different time and/or length scales?
- Which computational architectures and platforms will deliver the most benefit for the science of today and the science of the future?
- What advances in computer science and algorithms are needed to increase the efficiency with which supercomputers solve problems for SC?

- What operating systems, data management, analysis, model development, and other tools are required to make effective use of future-generation supercomputers?
- Is it possible to overcome the geographical distances that often hinder science by making all scientific resources readily available to scientists, regardless of whether they are at a university, national laboratory, or industrial setting?

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

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

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

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

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

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

Supporting Information

The computing and the networking capabilities required to meet SC needs exceed the state-of-the-art by a wide margin. Discussions of the extent to which the requirements of science exceed the current state-of –the-art can be found in a number of reports including: "Federal Plan for High-End Computing, Report of the High-End Computing Revitalization Task Force (HECRTF)" May 10, 2004, Appendices A-1, A-2, and A-3, (http://www.sc.doe.gov/ascr/hecrtfrpt.pdf); "A Science-Based Case for Large-Scale Simulation," Volume 1, July 30, 2003, (http://www.sc.doe.gov/ascr/Scalesreptvol1.pdf); "Theory and Modeling in Nanoscience, Report of the May 10-11, 2002 Workshop conducted by the Basic Energy Sciences and Advanced Scientific Computing Advisory Committees to the Office of Science, Dept. of Energy," (http://www.sc.doe.gov/ascr/TMN_rpt.pdf); "Integrated Simulation and Optimization of Magnetic Fusion Systems, Report of the FESAC Panel," November 2, 2002. (http://www.ofes.fusion.doe.gov/News/FSP_report_Dec9.pdf); and "High-Performance Networks for High-Impact Science, Report of the High-Performance Network Planning Workshop conducted August 13-15, 2002," (http://www.sc.doe.gov/ascr/high-performance_networks.pdf). Furthermore, the algorithms and software tools, libraries, and environments needed to accelerate scientific discovery through modeling and simulation are beyond the realm of commercial interest. To establish and maintain DOE's modeling and simulation leadership in scientific areas that are important to its mission, the MICS subprogram employs a broad, but integrated, research strategy. The MICS subprogram's basic research portfolio in applied mathematics and computer science provides the foundation for enabling research activities, which includes efforts to advance networking and to develop software tools, libraries, and environments. Results from enabling research supported by the MICS subprogram are used by computational scientists supported by other SC and DOE programs. This link to other DOE programs provides a tangible assessment of the value of the MICS subprogram for advancing scientific discovery and technology development through simulations.

In addition to its research activities, the MICS subprogram plans, develops, and operates supercomputer and network facilities that are available—24 hours a day, 365 days a year—to researchers working on problems relevant to DOE's scientific missions.

The Early Career Principal Investigator (ECPI) activity was initiated in FY 2002 for scientists and engineers in tenure track positions at U.S. universities. Seventeen awards were made in FY 2002, thirteen awards in FY 2003, and sixteen in FY 2004. Additional awards will be made in FY 2005 for this activity, pending peer review of applications. The goal of the ECPI activity is to support SC mission-related research in applied mathematics, computer science, and high-performance networks performed by exceptionally talented university investigators, who are at an early stage in their professional careers.

FY 2004 Accomplishments

- A collaboratory pilot project, the Collaboratory for Multi-scale Chemical Sciences (CMCS), has ushered in a new era of validated chemical reference data where all the pertinent experiments and computations can be considered by all the experts. A fifty-year-old question of the vaporization enthalpy of graphite, a thermochemical reference value for countless computational and experimental studies, has been resolved by an International Union of Pure and Applied Chemistry (IUPAC) Task Group empowered by CMCS capabilities. The new value for the enthalpy of formation of carbon atom in the gas phase is now more than twice as accurate as the previously accepted value. A new CMCS application called Active Thermochemical Tables enabled IUPAC group members to collaborate on the systematic reevaluation of previous experimental data, new state-of-the-art computational chemistry results, and comparison with other data. These new capabilities also enabled a group at DOE's Argonne National Laboratory to fully confirm a recent revision of the enthalpy of formation of the pivotal combustion and atmospheric radical, hydroxyl (OH), and to further reduce its uncertainty by a factor of ~6.5, thus removing a potential source of uncertainty in current chemical models.
- Under the Particle Physics Data Grid (PPDG) collaboratory project, robust, sustained, hands-off, production data transfer of terabytes of data has been enabled using GridFTP and Storage Resource Manager (SRM) implementations. Scientists on PPDG experiments moved terabytes (TB) of data routinely between institutions in the collaboration at a higher data transfer rate, a higher success rate for the transfer, high reliability in the resulting cataloging, and a decreased manpower effort in achieving the data transfer. This enables faster turnaround for analysis of the data, earlier physics results, and decreased risk in the building of new detectors and computing systems. The STAR detector at Brookhaven National Laboratory's (BNL's) Relativistic Heavy Ion Collider (RHIC) has seen a factor of ten increase in throughput for moving files between BNL and LBNL. A sustained robust, automated 5 TB data movement per week allows "next day" analysis. A factor of fifty improvement has been made in file discrepancies (now < 0.02% error rate). Publication of first results of the d+Au run last spring appeared in print in a record four months from the end of the run. The DØ experiment at the Fermi National Accelerator Laboratory (FNAL) moved over 50 TB of event data (20% of the run) to be analyzed off-site over the past six months. By using multiple streams in GridFTP, a factor of five improvement in throughput was made possible.
- The Earth System Grid (ESG) collaboratory project now provides the climate research community with a powerful new capability, and an excellent Grid-based foundation upon which to rapidly expand scientific services. The ESG has developed new data management capabilities that provide robust interoperability among DOE (High Performance Storage System [HPSS]) and National

Center for Atmospheric Research (NCAR) (Mass Storage System [MSS]) archival systems. It is now possible for a climate researcher to securely access through the ESG web portal all the climate modeling datasets (about 100) that have been developed over the past five years and download the portion of the dataset of interest. Additionally, ESG has been chosen as the vehicle for delivering climate model data to the international community for the fourth Intergovernmental Panel on Climate Change (IPCC) Assessment. The Program for Climate Model Diagnosis and Intercomparison (PCMDI), at the request of the World Meteorological Organization (WMO), hosted the primary ESG/IPCC services in the summer timeframe, 2004.

- Language Interoperability Improvements from Common Component Architecture — The Babel interoperability language allows software to be written in a variety of computer languages. Any one of C, C++, and Python can be used interchangeably in the same program. Recently Fortran, a language particularly important to scientific computing has also been added as a full peer to the rest of the Babel languages. Now software libraries using Babel are automatically callable from Fortran simulation codes. Conversely, Fortran teams now have a new capability to export their software to applications written in other languages. For example, all of the Common Component Architecture (CCA) frameworks and CCA-compliant component libraries are not only callable from Fortran, but the Fortran community can participate in developing fully CCA compliant components of their own. A concrete example of how Babel's language technology impacted science can be found in CCA's molecular geometry optimization activities. North West Chem (NWChem), Massively Parallel Quantum Chemistry (MPQC), Portable Extensible Toolkit for Scientific Computation (PETSC) and The Adaptive communication environment Object request broker (TAO) were combined into a single application with demonstrated improvements in robustness and efficiency over classic techniques. Babel was used in this effort since NWChem is written in Fortran, and MPQC in C++, while PETSC and TAO are written in C.
- Improved performance modeling framework predicted performance within 15% for scientific application codes—A performance model is an encapsulation of the performance characteristics of a given scientific application on a given computer system, which then can be used to predict the performance of the code on a new system. An accurate and easy-to-use performance modeling capability has many potential applications, including more effective system design, streamlined system procurements, and even easier tuning of programs by applications scientists. As part of the Performance Evaluation Research Center (PERC) SciDAC ISIC, University of California/San Diego researchers have developed a methodology for performance modeling that significantly simplifies this process, replacing in-depth analysis by automated tools. They developed and applied a new, faster and more accurate MetaSim framework to several application codes, and achieved performance predictions accurate to within 15%. In particular, the predictions for Hybrid Coordinate Ocean Model (HYCOM) and Cobalt60 were performed at various problem sizes for processor counts ranging from 64 to 256 on three different architectures.
- Rose Code Optimization—The Rose source code optimization project at Lawrence Livermore National Laboratory (LLNL) now includes support for all C++ language constructs, C, and United Parallel Code (UPC), and work to support Fortran 90 has begun in collaboration with Rice University. Performance increases up to a factor of 6 have been obtained by optimizing high level abstractions. Additional increases on large array operations, up to a factor of 15, have been obtained by combining high-level abstractions with aggressive loop optimizations. Program analysis of projects with more than a million lines of code and hundreds of files has been enabled through

extensive interactive visualization techniques and new database features that support storage of intermediate analysis results. This work impacts national and international research programs through strong collaborations with 14 universities and 4 DOE laboratories.

- High Performance Scientific Software Components—Argonne computer scientists, in close collaboration with the SciDAC Center for Component Technology for Terascale Simulation Software and the Common Component Architecture ISIC, have developed a variety of high-performance numerical components that are being used in prototype Partial Differential Equation (PDE)-based simulations as well as in full-blown applications in computational chemistry and climate modeling. Prototype software enables the automatic selection and configuration of components to suit the computational conditions imposed by a simulation and its operating environment. In collaboration with chemists at PNNL and Sandia National Laboratory (SNL), optimization components have been employed in the fundamental problem of molecular geometry optimization. Components based on the Toolkit for Advanced Optimization provide robust and efficient optimization solvers, which in turn can employ the parallel linear algebra capabilities within the PETSC. Experiments on a representative set of chemical structures have demonstrated improved robustness and efficiency.
- Design Patterns for Parallel Programming—Design patterns are an important tool for organizing and simplifying complex code development. The University of Illinois at Urbana-Champaign is identfying key programming patterns that occur in parallel scientific application, and to date 10 patterns have been documented: Pipes, Layers, Repositories, Master-Worker, Replicable, Inseparable, Divide and Conquer, Geometric, Recursive, and Irregular Mesh. Each of these patterns has been analyzed in terms of the decomposition paradigm (data decomposition vs. functional decomposition), ordering constraints, communication structure (local, tree, and irregular), and dependency structure (separable, deterministic/function dependency, and inseparable); and each of them has been documented in the style used by programming patterns dictionaries.
- Open-source compiler for Co-array Fortran—Co-Array Fortran (CAF) is a model for parallel programming that consists of a small set of extensions to the Fortran 90 programming language, which is widely used within the DOE community for scientific computing. CAF shifts the burden for managing the details of communication between a computer system's processors from the application developer to the CAF compiler. In January 2004, Rice University released an open-source CAF compiler prototype for evaluation by the science community and vendors. This project has already attracted significant interest from vendors of high performance computing systems. An ongoing effort is focused on refining the CAF language to further simplify writing scalable parallel programs and devising more sophisticated compiler technology to deliver highest possible performance for scientific computations on parallel systems.
- Scientific Application Performance on Modern Parallel Vector Systems—Researchers at LBNL are conducting a study to evaluate four diverse scientific applications from plasma physics, material sciences, astrophysics, and magnetic fusion. Performance comparisons have been made between vector-based (Earth Simulator and Cray X1), and leading superscalar-based (IBM Power3/4 and SGI Altix) platforms. This is the first international group to conduct a performance evaluation study at the Earth Simulator Center. Results demonstrate that the vector systems achieve excellent performance on the application suite—the highest of any architecture tested to date.

- Wide acceptance of open-source, high-end cluster software by industry and users—The ORNL Open Source Cluster Application Resources (OSCAR) cluster computing software for high-end computing continues to expand its capability and to increase its user base. The software has been downloaded by more than 130,000 groups around the world and is promoted by cluster vendors including Dell and Intel. The adoption of this system has expanded the number of software packages available to the cluster community, and OSCAR continues to reduce cluster total cost of ownership. It has simplified the job of software authors, system administrators, and ultimately the application user by providing a timely and much simpler method of supplying and applying software updates. The SciDAC Scalable Systems Software ISIC leverages OSCAR technology to simplify deployment for the end-user as well as application developers.

FY 2004 Awards

- R&D 100 Award to Los Alamos National Laboratory (LANL) Team — Every year, R&D Magazine recognizes the world's top 100 scientific and technological advances with awards for innovations showing the most significant commercial potential. The Computer Science project "Science Appliance" received an R&D 100 award for the year 2004. The Science Appliance software suite, called Clustermatic, is a set of tools that revolutionizes the way clustered systems are managed, monitored, administered, and run. Clustermatic increases reliability and efficiency, decreases node autonomy, and reduces administration costs, enabling commodity-based cluster systems to be more competitive with high-end supercomputers. Clustermatic also won the "Best Open-Source Cluster Solution" award at Cluster World 2004.
- Researchers at ANL and Northwestern University were awarded the Beale-Orchard-Hays Prize for Excellence in Computational Mathematical Programming. This prestigious prize is bestowed once every three years and is considered a major award from the Mathematical Programming Society. The presentation took place at the 18th International Symposium on Mathematical Programming in Copenhagen. The Argonne team received the award in recognition of their fundamental research in support of the development of the NEOS (Network-Enabled Optimization System) Server. Today's NEOS Server is a collaborative project that provides access to dozens of academic and commercial optimization solvers through an assortment of Internet interfaces. Over 120,000 job requests are handled annually, including optimization problems from academic, commercial, and government institutions.
- Innovative and Novel Computational Impact on Theory and Experiment (INCITE) Program—Some of the most significant work done at NERSC in 2004 was made possible by the INCITE Program, which supports a small number of computationally intensive large-scale research projects that are expected to make high-impact scientific advances through the use of a substantial allocation of computer time and data storage at the NERSC Center. In December 2003, SC selected three computational science projects to receive a total of 4.9 million hours of supercomputing time at the NERSC Center—10% of the total computing time available in FY 2004 on NERSC's Seaborg system. One of the INCITE projects, "Thermonuclear Supernovae: Stellar Explosions in Three Dimensions," has achieved unprecedented simulations of supernovae using NERSC's computing resources. The research group at the Center for Astrophysical Thermonuclear Flashes at the University of Chicago, typically uses 512 to 1,024 processors to test their applications. They expect to use 4,096 or more processors for their final calculations. So far they have calculated three Type Ia supernova explosion models, including one octant model with 8 kilometer resolution, which is

considered state of the art in this field. The group has also calculated one full-star model with 8 kilometer resolution and 30 kilometer ignition regions and one full-star model with 8 kilometer resolution and 50 kilometer ignition regions. These last two runs are the first of this kind ever calculated—no other group has produced full-star simulations before. They are now moving to 4 kilometer and 1 kilometer resolution models.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Mathematical, Computational, and Computer Sciences and Network Environment Research	**97,912**	**102,575**	**107,026**
▪ **Applied Mathematics**..	**22,553**	**26,428**	**28,995**

This activity supports research on the underlying mathematical understanding of physical, chemical, and biological systems, and on advanced numerical algorithms that enable effective description, modeling, and simulation of such systems on high-end computing systems. It directly supports SC Strategic Plan strategy 6.1. Research in Applied Mathematics supported by the MICS subprogram underpins computational science throughout DOE. Historically, the numerical algorithms developed under this activity have produced scientific advances through simulation that are as significant as those resulting from improvements in computer hardware. This activity supports research at DOE laboratories, universities, and private companies. Many of the projects supported by this activity involve research partnerships between DOE's national laboratories and universities. The activity supports research in a wide variety of areas of mathematics, including: ordinary and partial differential equations and solution methods, including techniques to convert equations into discrete elements and boundary integral methods; advanced treatment of interfaces and boundaries (fast marching and level set methods, and front tracking); numerical linear algebra (advanced iterative methods, general and problem-specific preconditioners, sparse solvers, and dense solvers); fluid dynamics (compressible, incompressible, and reacting flows, turbulence modeling, and multiphase flows); optimization (linear and nonlinear programming, interior-point methods, and discrete and integer programming); mathematical physics; control theory (differential-algebraic systems, order reduction, and queuing theory); accurate treatment of shock waves; "fast" methods (fast multipole and fast wavelet transforms); mixed elliptic-hyperbolic systems; dynamical systems (chaos theory, optimal control theory, and bifurcation theory); automated reasoning systems; and multiscale mathematics. This final area represents our most recent effort at focusing on those mission-related applications which span wide ranges of interacting length- and time-scales.

The FY 2006 budget continues the Computational Sciences Graduate Fellowship program at the current level of $3,500,000. The FY 2006 budget also includes $8,500,000 for the Atomic to Macroscopic Mathematics effort, an increase of $2,567,000 over the level planned for FY 2005. This increase will support a full year of funding for projects initiated in FY 2005.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Computer Science**	**19,402**	**19,909**	**24,380**

This activity supports research in computer science to enable computational scientists to effectively utilize high-performance computers to advance science in areas important to the DOE mission. This activity supports SC Strategic Plan strategies 6.1 and 6.3. DOE has unique requirements for high performance computing that significantly exceed the capability of software products from computer vendors. This activity supports computer science research in two general areas: the underlying software to enable applications to make effective use of computers with hundreds or thousands of processors as well as computers that are located at different sites; and large scale data management and visualization for both local data analysis and for circumstances where key resources and users are geographically distributed. Research areas include: tools to monitor the performance of scientific applications and enable users to improve performance and get scientific results faster; new programming models to simplify application code development; advanced techniques for visualizing very large-scale scientific data; and Next Generation Architecture (NGA) efforts to improve application performance through innovative next generation operating systems. Researchers at DOE laboratories and universities, often working in partnerships, propose and conduct this research.

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

Beginning in FY 2004, this activity incorporated the software research component of NGA to improve application performance and system reliability through innovative approaches to next generation operating systems. In FY 2006, the total funding for the NGA software research component is $6,659,000. This activity is coordinated with other agencies through the High End Computing University Research Activity (HEC URA), an outgrowth of the HECRTF. These activities will be modestly increased in FY 2006, especially in areas such as: performance analysis of innovative high-end architectures; frameworks for data intensive and visual computing; intelligent program development environments; application-specific problem solving environments; and common compile and runtime infrastructures and interfaces, where ASCR is the leader in the Federal agency research efforts. This research will play a key role in the interagency strategy for high end software development recommended in the HECRTF plan.

▪ **Computational Partnerships**..................................	**33,300**	**34,876**	**39,887**

This activity supports the amalgam of those activities previously titled "Advanced Computing Software Tools" and "Scientific Applications Partnerships." The advanced computing software tools part of this activity supports research and development activities that extend key results from applied mathematics and computer science research to develop integrated software tools that computational scientists can use in high performance scientific applications (such as characterizing and predicting phase changes in materials). These tools, which enable improved performance on high-end systems, are critical to the ability of scientists to attack the complex scientific and engineering problems that can only be solved with such systems. This activity directly supports SC Strategic Plan strategy 6.2.

In FY 2006, this activity will support the completion of the original Integrated Software Infrastructure Centers (ISICs) SciDAC activity, competitively selected in FY 2001. The ISICs funded under this activity focus on several important computational infrastructure problems including: structured and unstructured mesh generation for large simulations and high performance tools for solving partial differential equations on parallel computers; tools for analyzing the performance of scientific simulation software that uses thousands of processors; the development of data management and visualization software capable of handling terabyte scale data sets extracted from petabyte scale data archives; software for managing computers with thousands of processors; and software component technology to enable rapid development of efficient, portable, high performance parallel simulation software.

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

The scientific applications partnerships part of this activity, formerly titled Scientific Application Pilot Projects, supports collaborative research with computational scientists in other disciplines to apply the computational techniques and tools developed by other MICS activities to address problems relevant to the SC mission. This effort tests the usefulness of advances in computing research, transfers the results of this research to the scientific disciplines, and helps define opportunities for future research. The FY 2006 funding for this activity will allow the continuation of the multidisciplinary partnerships that were competitively selected in FY 2001. These projects are part of the SciDAC activity and are coupled to the ISICs. Areas under investigation include design of particle accelerators with the High Energy Physics (HEP) and Nuclear Physics (NP) programs, plasma turbulence in tokamaks with the Fusion Energy Sciences (FES) program, global climate change with the Biological and Environmental Research (BER) program, and combustion chemistry with the Basic Energy Sciences (BES) program. This activity directly supports SC Strategic Plan strategy 6.2.

The FY 2006 request includes funds to continue the partnerships with the BER Genomics: GTL program, the BES program in nanoscale science, and the FES program for the Fusion Simulation Project (FSP).

The FY 2006 request also includes $8,000,000 to initiate two competitively selected SciDAC institutes at Universities which can become centers of excellence in high end computational science in areas that are critical to DOE missions.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Distributed Network Environment Research**........	**22,657**	**21,362**	**13,764**

This activity supports the integration of activities previously described under the titles: "Network Research," "Collaboratory Tools," and "Collaboratory Pilots." This integrated activity builds on results of fundamental research in computer science and networking to develop an integrated set of software tools and services to support distributed scientific collaborations and provide end-to-end network performance well beyond the levels that can be achieved today. It advances the Network Environment vision by supporting research and development for advanced capabilities and technologies. For example, it includes standards-based network protocols and middleware that address challenging issues such as security, information location, and network performance that are encountered with ultra-high-speed data transfers, remote visualization, real-time remote instrumentation, and large-scale scientific collaboration. These tools provide a new way of organizing and performing scientific work, e.g., distributed teams and real-time remote access to SC facilities that offers the potential for increased productivity and efficiency. It will also enable broader access to important DOE facilities and data resources by scientists and educators throughout the country. It is particularly important to provide for efficient, high-performance, reliable, secure, and policy-aware management of large-scale data movement across the research enterprise.

Although this activity directly supports SC Strategic Plan strategy 6.2, it is being reduced in FY 2006 to enable MICS to provide computing resources to scientists across SC.

High Performance Computing and Network Facilities and Testbeds..	**95,967**	**123,608**	**94,400**
▪ **High Performance Computing Facilities and Testbeds**..	**79,387**	**105,320**	**76,112**

This activity represents the integration of activities previously described separately as NERSC and ACRTs. It includes NERSC ($37,868,000), resources at the ORNL Center for Computational Sciences (CCS) ($25,000,000), as well as a new activity to support Research and Evaluation Prototypes that enable SciDAC teams to evaluate the promise of future computer architectures for their applications ($13,244,000). These new testbeds will be selected competitively. This activity directly supports SC Strategic Plan strategy 6.4 through a portfolio of capabilities that range from Research and Evaluation Prototypes (R&E Prototypes) to Leadership Class Computers (LCCs) to High Performance Production Computing (HPPC). HPPC includes NERSC as well as resources at the ORNL CCS, which have completed their evaluation as R&E prototypes but have significant capability that can be cost-effectively delivered to science. This restructured approach will allow for a comparable level of high performance production computing capability to be provided more efficiently.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
• **National Energy Research Scientific Computing Center (NERSC)**	**32,906**	**37,868**	**37,868**

NERSC, located at the LBNL, delivers high-end capability computing services and support to the entire DOE SC research community. NERSC provides these services to the DOE community, to the other DOE laboratories, and to major universities performing work relevant to DOE missions. NERSC provides the majority of resources and services that are used to support SC SciDAC programs. The center serves 2,000 users working on about 700 projects. 35% of users are university based, 61% are in National Laboratories, 3% are in industry, and 1% are in other government laboratories. The major computational resource at NERSC is an IBM SP computer called NERSC 3e. The FY 2006 funding will support the continued operation of NERSC 3e at 10 teraflops peak performance, and a new computer system, which is focused on high performance capacity for scientific applications that do not scale well to more than 512 processors and are not well suited to the IBM SP with a peak performance over 6 teraflops. In addition, in FY 2006 a procurement will be conducted for the next generation of high performance resources at NERSC to be delivered in early FY 2007. These computational resources are integrated by a common high performance file storage system that enables users to easily use all the resources. The FY 2006 budget at NERSC will result in the elimination of some research activities, such as advanced computer architectures, numerical algorithms, and high performance file systems, which had previously been included in the NERSC budget. These research activities will now be completed within the peer reviewed computer science, applied mathematics, and partnership budget activities described earlier. This NERSC budget will maintain NERSC's world leading level of user support and enable introduction of new computing capacity to support critical science needs.

• **Center for Computational Sciences (CCS)**	**46,481**	**67,452**	**25,000**

The CCS, located at ORNL, provides high-end capability computing services to SciDAC teams and other DOE users on Eagle, a 720 processor IBM SP3 system and Cheetah, an 864 processor IBM SP4 system. As in the case at NERSC, these computational resources are integrated by a common high performance file storage system that enables users to easily use all the computational resources.

In FY 2004, the DOE leadership-class computing capability for science activity was initiated at CCS as the result of an open competition, and we anticipate that these facilities will become a major capability for science in the late FY 2005 timeframe with a Cray X1E system, the most capable system available to scientific users in the U.S., and a complementary Cray Red Storm System. These computers will become a part of the overall SC portfolio of HPPC resources in FY 2006. In FY 2006, the CCS will operate the computers acquired in FY 2004 and FY 2005 as resources for science. In order to enable effective operation of these resources for SciDAC teams and other scientists, all FY 2005 activities focused on the acquisition, testing, and evaluation of R&E prototype computer hardware testbeds to assess the prospects for meeting future computational needs of SC will be concluded by the end of FY 2005. Possible future

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

R&E prototype activities at the CCS will be competitively selected within the new Research and Evaluation Partnerships activity described below.

Related requirements for capital equipment, such as high-speed disk storage systems, archival data storage systems, and high performance visualization hardware, and general plant projects (GPP) funding are also supported. FY 2006 capital equipment requirements for these types of capital equipment will be reduced from FY 2005.

	FY 2004	FY 2005	FY 2006
• **Research and Evaluation Prototypes**	**0**	**0**	**13,244**

This new activity in FY 2006 will support Research and Evaluation prototypes to enable SciDAC teams to evaluate the potential of new computer architectures as tools for Science. These new testbeds will be competitively selected.

	FY 2004	FY 2005	FY 2006
▪ **High Performance Network Facilities and Testbeds**...	**16,580**	**18,288**	**18,288**

This activity supports the ESnet, a Wide Area Network (WAN) project that supports the scientific research mission of the DOE. The ESnet project/investment supports the agency's mission and strategic goals and objectives by providing DOE with interoperable, effective, and reliable communications infrastructure and leading-edge network services. ESnet supplies the DOE science community with capabilities not available through commercial networks or 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. ESnet provides the communications fabric that interconnects geographically distributed research facilities and large-scale scientific collaborations. ESnet supplies the critical infrastructure that links DOE researchers worldwide and forms the basis for advanced experimental research in networking, collaboratory tools, and distributed data-intensive scientific applications testbeds such as the national collaboratory pilot projects. This activity directly supports SC Strategic Plan strategy 6.4. ESnet provides network services through contracts with commercial vendors for advanced communications services including Asynchronous Transfer Mode (ATM), Synchronous Optical Networks (SONET) and Dense Wave Division Multiplexing (DWDM). ESnet provides interfaces between the network fabric it provides and peering arrangements with other Federal, education, and commercial networks, international research network connections, and the University Corporation for Advanced Internet Development (UCAID) Abilene network that provides high performance connections to many research universities.

In FY 2006, funds will be used to operate ESnet and to continue support for upgrading the capability of the ESnet backbone to over 10 Gigabits per second (Gbps) from its current capability of 1 Gbps. ESnet will control costs for connections of ESnet sites to the ESnet backbone by partnering with other organizations to develop metropolitan area fiber networks. Remaining funds will be used to upgrade networking hardware and services at high priority ESnet sites to exploit the enhanced performance capabilities of the backbone. FY 2006 capital equipment requirements remain at the same level as in FY 2005.

	FY 2004	FY 2005	FY 2006
Small Business Innovative Research (SBIR)/ Small Business Technology Transfer (STTR)	**0**	**6,285**	**5,629**

In FY 2004 $4,833,000 and $580,000 were transferred to the SBIR and STTR programs respectively. The FY 2005 and FY 2006 amounts shown are the estimated requirements for the continuation of the SBIR and STTR program.

(dollars in thousands)	FY 2004	FY 2005	FY 2006
Total, Mathematical, Information, and Computational Sciences	**193,879**	**232,468**	**207,055**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Mathematical, Computational & Computer Sciences and Distributed Network Environment Research	
▪ **Applied Mathematics**	
Increase in Applied Mathematics activity to support full year of funding for projects initiated in FY 2005 as part of Atomic to Macroscopic Mathematics effort.	+2,567
▪ **Computer Science**	
Enhance NGA computer science research to enable effective software for high performance computers.	+4,471
▪ **Computational Partnerships**	
Increase in partnership activities resulting from recompetition of SciDAC activities and initiation of new university based competition for SciDAC Institutes which can become centers of excellence in scientific areas critical to the missions of DOE.	+5,011
▪ **Distributed Network Environment Research**	
This activity is being reduced and focused on network research and middleware to enable MICS to provide computer resources to scientists across the SC.	-7,598
Total, Mathematical, Computational & Computer Sciences and Distributed Network Environment Research	**+4,451**

	FY 2006 vs. FY 2005 ($000)
High Performance Computing & Network Facilities and Testbeds	
▪ **High Performance Computing Facilities and Testbeds**	
This reduction reflects the completion in FY 2005 of evaluation activities at the CCS, rescoping of the Leadership Class effort to operate computers acquired in prior years as resources for science, and initiation of a new competitive program to select promising future architecture computing testbeds.	-29,208
SBIR/STTR	
Decrease in SBIR/STTR due to decrease in operating expenses.	-656
Total Funding Change, Mathematical, Information, and Computational Sciences	**-25,413**

Laboratory Technology Research

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Laboratory Technology Research					
Laboratory Technology Research	2,916	0	0	0	0.0%
SBIR/STTR	0	0	0	0	0.0%
Total, Laboratory Technology Research	2,916	0	0	0	0.0%

Description

The Laboratory Technology Research (LTR) subprogram is brought to a successful conclusion in FY 2004 with orderly completion of all existing Cooperative Research and Development Agreements (CRADAs). The mission of the LTR subprogram was to support high-risk research that advances science and technology to enable applications that could significantly impact the Nation's energy economy. LTR fostered the production of research results motivated by a practical energy payoff through cost-shared collaborations between SC laboratories and industry. The termination of the LTR subprogram does not mean that technology transfer activities have ended; rather, due to the impact of this subprogram, these activities are now institutionalized as a part of the process of doing research at DOE sites.

Benefits

LTR supported ASCR's contribution to DOE's mission of world-class scientific research capacity by promoting the transfer of these research results to the private sector. The success of this program has institutionalized these processes in all of the programs within SC; therefore, these processes are now integrated into the other programs and the LTR subprogram is no longer needed.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Laboratory Technology Research	**2,916**	**0**	**0**

This activity supported research to advance the fundamental science at SC laboratories toward innovative energy applications. Through CRADAs, the SC laboratories entered into cost-shared research partnerships with industry, typically for a period of three years, to explore energy applications of research advances in areas of mission relevance to both parties. The existence of the LTR subprogram fostered the institutionalization of technology transfer activities at DOE sites. Now that these activities are institutionalized, a separate program to fund them is no longer necessary.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
SBIR/STTR	**0**	**0**	**0**

In FY 2004, $75,000 and $9,000 were transferred to the SBIR and STTR programs respectively.

Total, Laboratory Technology Research....................	**2,916**	**0**	**0**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Capital Equipment	9,185	8,000	6,000	-2,000	-25.0%

Biological and Environmental Research

Funding Profile by Subprogram

	(dollars in thousands)				
	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Biological and Environmental Research					
Life Sciences	200,320	204,011	-1,175[a]	202,836	204,035
Climate Change Research	137,997	142,959	-1,965[a]	140,994	142,959
Environmental Remediation	104,758	105,272	-816[a]	104,456	94,694
Medical Applications and Measurement Science	180,973	124,348	-642[a]	123,706	14,000
Subtotal, Biological and Environmental Research	624,048	576,590	-4,598	571,992	455,688
Construction	0	10,000	-80[a]	9,920	0
Total, Biological and Environmental Research	624,048[bc]	586,590	-4,678	581,912	455,688

Public Law Authorization:
Public Law 95-91, "Department of Energy Organization Act"

Mission

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

Benefits

BER supports DOE's mission of protecting our national and economic security by providing world-class scientific research capacity and advancing scientific knowledge by supporting world-class, peer-reviewed scientific results in biology and environmental science whose results are published in the scientific literature. Basic biological and environmental research has broad impacts on our health, our environment, and our energy future. An ability to predict long-range and regional climate enables effective planning for future needs in energy, agriculture, and land and water use. Biotechnology solutions are possible for DOE energy, environmental, and national security challenges by understanding complex biological systems and developing computational tools to model and predict their behavior.

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[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes an increase of $53,250,000 for supplemental appropriations, and a reduction of $3,796,000 rescinded in accordance with P.L. 108-137, the Consolidated Appropriations Act, 2004.
[c] Includes reduction of $15,541,000, which was transferred to the SBIR program and $1,865,000, which was transferred to the STTR program.

Understanding the global carbon cycle and the associated role and capabilities of microbes and plants can lead to solutions for reducing carbon dioxide concentrations in the atmosphere. Understanding the complex role of biology, geochemistry, and hydrology beneath the Earth's surface will lead to improved decision making and solutions for contaminated DOE weapons sites. Both normal and abnormal health—from normal human development to cancer to brain function—can be understood and improved using radiotracers, advanced imaging instruments, and novel biomedical devices. Understanding the biological effects of low doses of radiation can lead to the development of science-based health risk policy to better protect workers and citizens.

Strategic and Program Goals

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

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

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

Program Goal 05.21.00.00: Harness the Power of Our Living World – Provide the biological and environmental discoveries necessary to clean and protect our environment, offer new energy alternatives, and facilitate the entrainment of physical sciences advances in the biomedical field.

Contribution to Program Goal 05.21.00.00 (Harness the Power of Our Living World)

BER contributes to Program Goal 05.21.00.00 by advancing fundamental research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical applications. BER supports leading research programs that provide world-class, merit-reviewed research results. Discoveries at these scientific frontiers will bring revolutionary and unconventional solutions to some of our most pressing and expensive challenges in energy and the environment.

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

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

In addition, BER plans, constructs, and operates reliable, world-class scientific facilities to serve thousands of researchers at universities, national laboratories, and private institutions from all over the world. Activities include structural biology research beam lines at the synchrotron light sources and neutron sources; the operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL) (including the Molecular Sciences Computing Facility) where research activities underpin long-term environmental remediation and other DOE missions in energy and national security; the Production Genomics Facility; the Laboratory for Comparative and Functional Genomics ("Mouse House"); and the climate change research facilities – the Atmospheric Radiation Measurement (ARM) and the Free-Air Carbon Dioxide Enrichment (FACE) facilities.

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

- **Life Sciences:** Characterize the multi protein complexes (or the lack thereof) involving a scientifically significant fraction of a microbe's proteins. Develop computational models to direct the use and design of microbial communities to clean up waste, sequester carbon, or produce hydrogen.
- **Climate Change Research:** Deliver improved climate data and models for policy makers to determine safe levels of greenhouse gases for the earth's system. By 2013, substantially reduce differences between observed temperature and model simulations at subcontinental scales using several decades of recent data.
- **Environmental Remediation:** Develop science-based solutions for clean-up and long-term monitoring of DOE contaminated sites. By 2013, a significant fraction of DOE's long-term stewardship sites will employ advanced biology-based clean-up solutions and science-based monitors.
- **Medical Applications and Measurement Science:** Develop intelligent biomimetic electronics that can both sense and correctly stimulate the nervous system.[a]
- **Facilities:** Manage facilities operations to the highest standards of overall performance using merit evaluation with independent peer review.

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[a] This indicator is not a PART measure.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 05.21.00.00 (Harness the Power of Our Living World)					
Life Sciences					
Increase the rate of DNA sequencing: Produce at least 5.8 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing; Produce at least 12.7 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing: Produce at least 14 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing: Produce at least 20 billion base pairs of high quality DNA microbial and model organism genome sequence. [Met Goal]	Increase the rate of DNA sequencing -- Number (in billions) of base pairs of high quality (less than one error in 10,000 bases) DNA microbial and model organism genome sequence produced annually. FY 2005 at least 28 billion base pairs will be sequenced.	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.
Climate Change Research					
Improve climate models: Documented consistency between observed temperature changes in the atmosphere and ocean and model simulated temperature changes using the Parallel Climate Model designed to run on the massively parallel computers at DOE laboratories. [Met Goal]	Improve climate models: Released a new coupled climate model with a horizontal resolution of 2.8 degrees (longitude and latitude) in the atmosphere and 0.7 degrees in the ocean and sea ice components, compared to the previous version with a resolution of 2.8 degrees in the atmosphere and 2.0 degrees in the ocean. Executed an 800-year equilibrium climate simulation with the new model. [Met Goal]	Improve climate models: Constructed a climate model for the next round of IPCC Working Group 1 Assessment simulations. This model increased the realism of the coupled atmosphere-ocean-land surface-sea ice system through improvements in the physical parameterizations, particularly the cloud sub models. The standard model increased the horizontal resolution to 1.4 degrees in the atmosphere and maintained the 0.7 degree resolution in the ocean and sea ice components. More objective and systematic methods to test (evaluate) the performance of both the model components (i.e., atmosphere, ocean, land surface, and sea ice sub models) as well as the fully coupled model, were applied. [Met Goal]	Improve climate models: Implement a model test bed system to incorporate climate data rapidly into climate models to allow testing of the performance of sub-models (e.g. cloud resolving module) and model parameters by comparing model simulations with real world data from the ARM sites and satellites. [Met Goal]	Improve climate models: Implement three separate component submodels (an interactive carbon cycle submodel, a secondary sulfur aerosol submodel, and an interactive terrestrial biosphere submodel) within a climate model and conduct 3-4 year duration climate simulation using the fully coupled model.	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

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Environmental Remediation					
Determine scalability of laboratory results in field environments: Demonstrated that uranium concentrations in groundwater can be significantly decreased using bioremediation at the Field Research Center at ORNL. [Met Goal]	Determine scalability of laboratory results in field environments: Using genomic sequencing data of key bioremediation microbes, such as Geobacter, Deinococcus, and Shewanella, determined that common soil microbes produce organic compounds that interact with radionuclides, such as plutonium, providing the molecular understanding for the detection and transformation of radionuclides in subsurface environments. [Met Goal]	Determine scalability of laboratory results in field environments: Identified naturally occurring microbial populations responsible for transformation of metals and radionuclides at DOE contaminated sites. [Met Goal]	Perform combined field/laboratory/modeling to determine how to interpret data at widely differing scales: Quantify contaminant immobilization and remobilization by different factors: 1. natural microbial mechanisms; 2. chemical reactions with minerals; and 3. colloid formation. [Met Goal]	Determine scalability of laboratory results in field experiments - Conduct two sets of field experiments to evaluate biological reduction of chromium and uranium by microorganisms and compare the results to laboratory studies to understand the long term fate and transport of these elements in field settings.	Develop predictive model for contaminant transport that incorporates complex biology, hydrology, and chemistry of the subsurface. Validate model through field tests.
Medical Applications and Measurement Science[1]					
Advance blind patient sight: Developed an *in vitro* testing system to test all prototype artificial retina devices for safety before inserting device into a human eye. [Met Goal]	Advance blind patient sight: Developed technology to micromachine new flexible biocompatible material to be used as a platform for multi-electrode array artificial retina. [Met Goal]	Advance blind patient sight: Developed and tested materials for platform and sealants for a prototype artificial retina- a microelectronic array to be used for the treatment of blindness. [Met Goal]	Advance blind patient sight: Complete fabrication of 60 microelectrode array for use as an artificial retina and tested in animal subject. [Met Goal]	Advance blind patient sight: Complete testing on a 60 microelectrode array artificial retina and insert prototype device into a blind patient.	Advance blind patient sight: Begin testing of prototypes for 256 microelectrode array artificial retina.
All BER Facilities					
Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]	*Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]*	*Maintain and operate BER facilities such that achieved operation time is on average greater than 90% of the total scheduled annual operation time. [Met Goal]*	*Maintain and operate BER facilities 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.*	*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.*

[1] This is not a PART measure.

Means and Strategies

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

The BER program will continue its investments in core fundamental science and technologies needed to address the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. Of highest priority will be the development of a new research infrastructure needed to understand fundamental biological principles underlying the function and control of biological systems, the heart of the Genomics: GTL program. A combination of new research infrastructure coupled with well-integrated, interdisciplinary research teams will form the basis of a new approach for studying complex biological systems and for using those systems to solve critical problems in energy and environmental cleanup.

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

BER also plays a key role in constructing and operating a wide array of biological and environmental user facilities for the Nation's researchers.

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

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

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

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

Validation and Verification

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

Program Assessment Rating Tool (PART) Assessment

The Department implemented a tool to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. BER has incorporated feedback from OMB into the FY 2005 and FY 2006 budget request and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave BER a high score of 86% overall which corresponds to a rating of "Effective." OMB found that the program is well coordinated with other federal research agencies, uses targeted grant solicitations that convey the long term goals of the program, and funds high risk research that regularly delivers important results. The assessment found that BER has developed a limited number of adequate performance measures that are continued for FY 2006. These measures have been incorporated into this budget request, BER grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain these complex scientific measures, the Office of Science has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Biological and Environmental Research Advisory Committee (BERAC) and also available on the website, will guide tri-annual BERAC 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 Report. In response to PART findings, BER 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. The COV report is available on the web at http://www.science.doe.gov/ober/berac/ERSDCOV.pdf. BER developed an action plan to respond to the findings and recommendations of the COV within 30 days of receiving the report. This action plan is also available on the web at http://www.science.doe.gov/ober/berac/Reports.html.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.21.00.00 Harness the Power of Our Living World			
Life Sciences	200,320	202,836	204,035
Climate Change Research	137,997	140,994	142,959
Environmental Remediation	104,758	104,456	94,694
Medical Applications and Measurement Science	180,973	123,706	14,000
Construction	0	9,920	0
Total, General Goal 5, World-Class Scientific Research Capacity	624,048	581,912	455,688

Overview

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

The Opportunity

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

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

The Challenges

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

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

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

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

The Investment Plan

All BER R&D investments are evaluated against the Administration's R&D Investment criteria that include research and user facility relevance, quality, and performance. BER will continue its investments in core technologies and fundamental science needed to address these daunting challenges. We believe that the most important scientific advances in the 21^{st} century will occur at the interfaces between scientific disciplines such as biology, physics, chemistry, engineering, and information science. BER investments at these interfaces will enable: (1) the development of a new research infrastructure for understanding the function and control of biological systems that can be used to solve critical problems in energy and the environment; (2) an improved ability to predict climate on global and regional scales; (3) development of strategies to remove excess carbon dioxide from the atmosphere; (4) new science-based strategies for the remediation, and long-term monitoring of the environment; and (5) the development of unique devices and technologies for the medical community that improve our Nation's health.

How We Work

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

Advisory and Consultative Activities

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

Facility Operations Reviews

BER facility operations are monitored by peer reviews and user feedback. BER facility operations have also been reviewed by BERAC and by an OSTP interagency working group evaluating structural biology user facilities. The Office of Science's Construction Management Support Division has reviewed BER's Joint Genome Institute. BER manages these facilities in a manner that meets user requirements as indicated by achieving performance specifications while protecting the safety of workers and the environment. Facilities are operated reliably and according to planned schedules. Facilities are also maintained and improved to remain at the cutting edge of technology and scientific capability.

Program Reviews

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

At the highest level, regular reviews of individual BER program elements and of the entire BER research program are conducted by BERAC. As noted above, BER also benefits from interagency and international reviews of programs such as the Climate Change Science Program and the structural biology research program, including reviews by Boards and Committees of the National Academies of Science.

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

Planning and Priority Setting

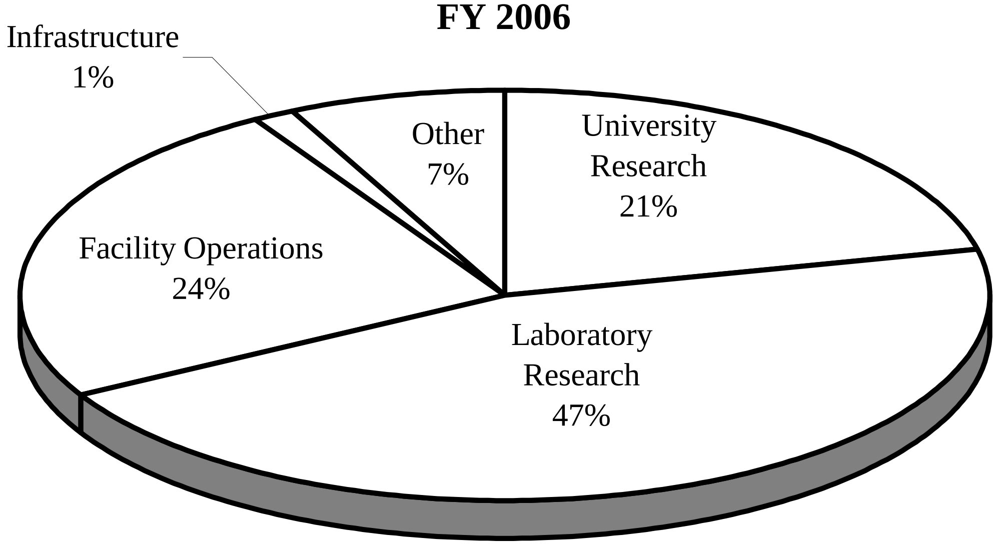
BER prides itself on supporting research and developing new research initiatives that lead the way across many fields of science and that effectively bring together many different disciplines, including biology, chemistry, engineering, computing, and the physical sciences. Merit reviews and user feedback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

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

How We Spend Our Budget

The BER budget has three major components: basic research at universities (21%); basic research at national laboratories (47%); and user facility support (24%). The remaining 8% includes general plant projects and equipment that supports the research infrastructure at the National Laboratories (1%) and all other research activities (primarily other federal agencies and industry (7%)). Research at national laboratories also includes Unmanned Aerial Vehicles and other elements that represent a research infrastructure for the scientific community that includes both university and laboratory scientists. BER's user facilities include the infrastructure at synchrotron and neutron sources for structural biology and the environmental sciences, operation and equipment for the Environmental Molecular Sciences Laboratory (EMSL), support for high-throughput DNA sequencing at the Joint Genome Institute, Atmospheric Radiation Measurement Infrastructure, Free-Air CO_2 Enrichment (FACE) experimental facilities, and for the Laboratory for Cooperative and Functional Genomics ("Mouse House").

Biological and Environmental Research Budget Allocation FY 2006



Research

In FY 2006, the BER program will support fundamental research in climate change, environmental remediation, genomics, proteomics, radiation biology, and medical sciences at over 200 public and private research institutions in over 40 states and at 14 DOE laboratories in 10 states. This research will be conducted in over 1,000 different research projects by over 2,500 researchers and students. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.

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

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

- ***National Laboratory Research:*** Research projects at national laboratories are most often multi-investigator team projects that take advantage of unique resources, capabilities, or facilities found at the national laboratories. Researchers at the national laboratories collaborate extensively with academic researchers supported by BER as well as with academic users of the BER facilities infrastructure including the EMSL, ARM, FACE, Natural and Accelerated Bioremediation Research (NABIR) Field Research Center, the Joint Genome Institute (JGI), and the structural biology and environmental user facilities at the synchrotron and neutron sources.

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

BER Leadership and Unique Roles

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

- Manage research on microbes for energy and the environment, and work with the Advanced Scientific Computing Research program to develop the computational methods and capabilities needed to advance understanding of complex biological systems, predict their behavior, and use that information to address DOE needs.
- Provide the facilities, instrumentation, and technology needed to (1) characterize the multi-protein complexes that result in microbial products and processes of use to DOE, and (2) determine the functional repertoire of complex microbial communities that can be used to address DOE needs.
- Provide world-class structural biology user facilities.
- Provide cutting edge technologies, facilities (including high-throughput community DNA sequencing capabilities), and resources, including animal models, for genomics research.
- Provide world-class scientific user facilities for environmental and climate change research.
- Provide world leadership in low dose radiation research.
- Provide world leadership in the understanding of how metal and radionuclide contaminants interact with the environment and how environments respond to their presence.
- Provide world leadership in ground-based measurement of clouds and atmospheric properties to resolve key uncertainties in climate change, through the ARM program.
- Develop advanced predictive capabilities using coupled climate models on the Nation's premier computers for decade-to-century long simulations of climate change.

- Support fundamental research on carbon sequestration to develop technologies that enhance the uptake of carbon in terrestrial and ocean ecosystems.
- Provide the scientific knowledge and enabling discoveries to reduce the risks and costs associated with the cleanup of the DOE weapons complex and provide a basis for similar mission needs related to energy, water, and the disposal and storage of waste.
- Provide leadership in the development of reagents and imaging technologies for wide use in the medical and research communities.
- Enable interdisciplinary teams of scientists to use the unique resources in physics, chemistry, material sciences, and biology at the National Laboratories to develop novel medical applications.
- Provide world leadership in the development of intelligent micro machines that interface with the brain and spinal cord to overcome disabilities.
- Ensure that the rights and welfare of human research subjects at the Department are protected while advances in biomedical, environmental, nuclear, and other research lead to discoveries that benefit humanity.

Significant Program Shifts

Based on the PART findings, the confirmation of the BER long term Performance Measures, and program evaluation using the R&D investment criteria, BER significant program shifts for FY 2006 will focus on:

- As part of the BER program evaluation process, BERAC has confirmed that Genomics: GTL facilities are of the highest relevance to BER. Research to underpin the development and design of the technologies to be incorporated into these facilities is funded as part of the Genomics: GTL program.
- The Ethical, Legal, and Societal Issues program will include activities applicable to biotechnology and nanotechnology in cooperation with other programs in the Office of Science.
- Moving the management of the National Institute for Global Environmental Change (NIGEC) from the University of California at Davis to BER will increase performance by reducing overhead costs and freeing up funds to support additional relevant and high quality research. This action has been confirmed by the BERAC COV for the Climate Change Research program. The number of NIGEC regional centers will also be reduced from six to four by holding an open competition for the four centers. NIGEC will be managed through a cooperative agreement with each of the four centers selected through the competition. Universities wishing to serve as a host institution of one of the four NIGEC regional centers can compete for a center in FY 2005 for FY 2006 funding. The existing cooperative agreement with the University of California at Oakland that currently operates NIGEC for DOE will be discontinued to further reduce overhead costs. NIGEC will continue to solicit proposals for research relevant to BER's climate change research priorities and needs from investigators in universities and other non-Federal research institutions within each of the newly defined regions covered by the four NIGEC centers to be selected.
- Based on scientific and program relevance, ocean carbon sequestration field research on the environmental effects of ocean carbon sequestration is completed and the results of previous studies are modeled and new research on microbial processes that affect carbon transformation and sequestration in terrestrial soils using technologies, capabilities, and methods developed by the GTL program will be initiated.

- Based on fiscal restraints, BER will focus research activities on higher priorities including GTL and Climate Change Research in support of Departmental goals and objectives. Funding reductions are initiated in the Environmental Remediation Research subprogram and the Medical Applications and Measurement Science Research subprogram, accordingly. The current research activities will be phased out in FY 2005.
- Based on the BERAC COV findings for the Environmental Remediation Research subprogram, the research activities are integrated into a single program to increase the efficiency of the activities and better address the BER long term goals in environmental remediation research. This includes having the Savannah River Ecology Laboratory (SREL) compete for research funding within our overall research program rather than being a separately funded activity.
- Our enhanced climate change research will deliver earth system models that will provide regional climate predictions.

Genomics: GTL Research

The FY 2006 budget includes funds for the continued expansion of the Genomics: GTL program—a program at the forefront of the biological revolution. This program employs a systems approach to biology at the interface of the biological, physical, and computational sciences to address DOE's energy, environment, and national security mission needs. This research will continue to more fully characterize the inventory of multi-protein molecular machines found in selected DOE-relevant microbes and higher organisms. It will determine the diverse biochemical capabilities of microbes and microbial communities, especially as they relate to potential biological solutions to DOE needs, found in populations of microbes isolated from DOE-relevant sites. Support for Microbial Genomics research as a separate research activity is terminated to consolidate all microbial research within Genomics: GTL. Support of structural biology, human genome, and health effects research is reduced to support GTL research. GTL research will provide the scientific community with knowledge, resources, and tools that benefit large numbers of research projects with positive impacts on more scientists and students than are negatively impacted by the initial reduction.

Climate Change Science Program

In 2003, the Administration launched the Climate Change Research Initiative (CCRI) to focus research on areas where substantial progress in understanding and predicting climate change, including its causes and consequences, is possible over the next five years. The CCRI was then combined with the existing U.S. Global Change Research Program (USGCRP) to form a combined USGCRP/CCRI managed as the Climate Change Science Program (CCSP) by the cabinet-level Committee on Climate Change Science and Technology Integration. (The BER request for CCSP for FY 2006 is $132,109,000.) DOE, in conjunction with its interagency partners, including NSF, NASA, NOAA, USDA, Interior, and EPA, will continue to focus its Climate Change Research in CCSP priority areas. These areas include advanced climate modeling, critical climate processes (including effects of clouds and water vapor on the atmospheric radiation balance), carbon cycling, atmospheric composition (with a focus on both greenhouse gas concentrations and effects of various aerosols on climate), effects of climate change on important terrestrial ecosystems, and the development and evaluation of tools for assessing the costs and benefits of climate change mitigation options. The deliverables from this BER research will be highlighted by information useful to policy makers.

In FY 2006, BER will contribute to the CCRI from four programs: Terrestrial Carbon Processes, Climate Change Prediction, ARM, and Integrated Assessment. Activities will be focused on (1) helping to resolve the North American carbon sink question (i.e., the magnitude and location of the North

American carbon sink); (2) deployment and operation of a mobile ARM Cloud and Radiation Testbed facility to provide data on the effects of clouds and aerosols on the atmospheric radiation budget in regions and locations of opportunity where data is lacking or sparse; (3) using advanced climate models to simulate potential effects of natural and human-induced climate forcing on global and regional climate and the potential effects on climate of alternative options for mitigating increases in human forcing of climate; and (4) developing and evaluating assessment tools needed to study costs and benefits of potential strategies for reducing net carbon dioxide emissions.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all Office of Science mission areas with the goal of achieving breakthrough scientific advances via computer simulation that are impossible using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit terascale computing and networking resources. The program is bringing computation and simulation to parity with experiments and theory in the scientific research enterprise as demonstrated by major advances in climate modeling and prediction, plasma physics, particle physics, accelerator design, astrophysics, chemically reacting flows, and computational nanoscience.

In FY 2006, BER will continue to advance the science of climate modeling by coupling models of different components of the earth system related to climate and by significantly increasing the spatial resolution of global climate models. These SciDAC-enabled activities will allow climate scientists to gain unprecedented insights into potential effects of energy production and use on the global climate system.

Scientific Facilities Utilization

The BER request includes funds to maintain support of the Department’s major scientific user facilities. BER has expanded the definition of a scientific user facility to include facilities such as structural biology research beam lines at the synchrotron light sources and neutron sources; the operation of the William R. Wiley Environmental Molecular Sciences Laboratory where research activities underpin long-term environmental remediation and other DOE missions in energy and national security; the Production Genomics Facility; the Laboratory for Comparative and Functional Genomics (“Mouse House”); and the ARM and FACE facilities. With this funding, BER will provide for the operation of the facilities, assuring access for scientists in universities, federal laboratories, and industry. BER will also leverage both federally and privately sponsored research to maintain support for and operation of these facilities.

BER will maintain and operate its user facilities so that the achieved operation time will be greater than 95%, on average, of total scheduled annual operation.

User Statistics

	FY 2004	FY 2005	FY 2006
	Actual	Estimate	
EMSL			
Optimal hours	4,365	4,365	4,365[a]
Scheduled hours	4,365	4,365	4,365[a]
Operation Time	95%	95%	>95%[a]
Users	1400	1400	1600
Production Genomics Facility			
Optimal hours	8,400	8,400	8,400[b]
Scheduled hours	8,400	8,400	8,400[b]
Operation Time	>98%	>98%	>98%[b]
Users	50	50	80
Laboratory for Comparative and Functional Genomics ("Mouse House")			
Optimal hours	3,536	3,536	3,536[c]
Scheduled hours	3,536	3,536	3,536[c]
Operation Time	>99%	>99%	>99%[c]
Users	20	20	20
Atmospheric Radiation Measurement (ARM)			
Optimal hours	7,862	7,862	7,862[d]
Scheduled hours	7,862	7,862	7,862[d]
Operation Time	>98%	>98%	>98%[d]
Users	765	800	800
Free Air Carbon Dioxide Enrichment (FACE)			
Optimal hours	3,966	3,966	3,966[e]
Scheduled hours	3,966	3,966	3,966[e]
Operation Time	>95%	>95%	>96%[e]
Users	200	195	200

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

[a] Approved by BERAC May 2004. Overall average scheduled operating hours estimated at approximately 12 hours per day, 365 days per year.
[b] Approved by BERAC May 2004. The PGF DNA sequencing facility now operates almost continuously.
[c] Approved by BERAC May 2004. Definition of an operating hour was changed by BERAC from 24 hours per day, 7 days per week, 52 weeks per year to i.e., when staff are present at the facility 12 hours a day Monday-Friday and 4 hours a day on the weekend.
[d] Approved by BERAC May 2004. Allows for weather related downtime based on climatology, e.g., lightning strikes, hail, extreme winds, and cold events.
[e] Approved by BERAC May 2004. Definition of an operating hour was changed by BERAC from a sum of 4 sites to the average over the 4 sites.

Construction and Infrastructure

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

For BER activities the capital equipment is held approximately at the FY 2005 level.

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

Workforce Development

Workforce development is an integral and essential element of the BER mission to help ensure a science-trained workforce, including researchers, engineers, science educators, and technicians. The research programs and projects at the National Laboratories, universities, and research institutes actively integrate undergraduate and graduate students and post-doctoral investigators into their work. This "hands-on" approach is essential for the development of the next generation of scientists, engineers, and science educators. Specific fellowship programs are also sponsored by BER to target emerging areas of need in global change research. About 1,400 graduate students and post-doctoral investigators will be supported at universities and at National Laboratories in FY 2006, including those conducting research at BER user facilities with BER or other funds. BER will continue its support for graduate students and post-doctoral investigators in FY 2006.

Office of Science user facilities are playing an increasingly important role in workforce development. Graduate and postdoctoral students from many different disciplines use Office of Science user facilities. For example, researchers in the environmental, biological, and physical sciences use the instruments at EMSL and the synchrotron light sources. The unique capabilities at these facilities provide graduate and postdoctoral students the opportunity to participate in leading-edge research. Approximately half of all DOE facility users are graduate or postdoctoral students, for example some 600 to 700 students will conduct research at EMSL in FY 2006. Students who use EMSL receive their funding from a number of sources including the EMSL user (operating) budget, other BER projects, other DOE programs, other federal agencies, international sponsors, and private industry.

The fastest growing user community at the synchrotron light sources is environmental researchers. BER is working with BES (that manages these facilities) to prepare a plan for BER support to develop and operate environmental user stations at DOE synchrotron light sources and for user support for these stations. In addition, BER is working with scientists in the environmental research community who receive funding from DOE and from other agencies to develop more environmental science user stations at the synchrotron light sources that provide both technical support to users and that are user friendly. This will further increase the impact of SC facilities on workforce development in important research fields, such as the environmental sciences.

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

University-based scientists are the principal users of BER user facilities. University scientists also form the core of the science teams in the Climate Change Research Programs that network with the broader academic community as well as with scientists at DOE laboratories and other agencies, such as the National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration. In addition, university-based scientists are funded through Requests for Applications across the entire BER program including genomics, structural biology, low dose radiation research, climate change research, bioremediation research, medical imaging, and radiopharmaceutical development. Furthermore, university scientists work in close partnership with scientists at National Laboratories in many other BER programs including genomics, and carbon sequestration research.

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	883	855	650
Average Size / Duration	$219,000/yr-3 yrs	$300,000/yr-3yrs	$250,000/yr-3yrs
# Laboratory Projects	400	400	375
# Permanent Ph.D.s[a] (FTEs)......	1,517	1,540	1,260
# Postdoctoral Associates[b] (FTEs)	372	400	280
# Graduate Students[b] (FTEs)	488	500	410
# Ph.D.s awarded[c]	NA	NA	100

[a] Estimated. Information is not readily available on the total number of permanent Ph.D. scientists associated with each research project. In addition to the principal investigator for each research project funded by BER, individual projects typically have between 1 and 20 additional Ph.D.-level scientists who are funded collaborators. Information on scientific collaborators is not routinely tracked.
[b] Estimated for national laboratory projects.
[c] Information is not available on the number of Ph.D.s awarded as a result of BER funded research at universities or national laboratories. Such data will be collected for FY 2006.

Life Sciences

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Life Sciences					
Structural Biology	23,863	21,892	15,300	-6,592	-30.1%
Molecular and Cellular Biology	102,955	100,768	111,809	+11,041	+10.9%
Human Genome	63,578	64,572	64,226	-346	-0.5%
Health Effects	9,924	10,237	7,321	-2,916	-28.5%
SBIR/STTR	0	5,367	5,379	+12	+0.2%
Total, Life Sciences	200,320	202,836	204,035	+1,199	+0.6%

Description

The mission of the Life Sciences subprogram is to foster fundamental research in the biological and life sciences that will provide new insights and advance knowledge of the life sciences to underpin the Department of Energy's mission needs. Biotechnology offers the promise of revolutionary solutions to energy and environmental challenges facing DOE and the Nation. Fundamental research in the Life Sciences subprogram will deliver a new knowledge base for cost effective cleanup of environmental contamination, design of new strategies for enhanced capture of atmospheric carbon dioxide, and increased bio-based sources of fuel or electricity. The program will also deliver new knowledge underpinning rigorous, cost-effective standards to protect the health of DOE cleanup workers and the public, and for science-based decisions on DOE site cleanup.

Benefits

Fundamental research is supported in genomics and the health effects of low dose radiation. DNA sequencing is used to understand the genetic and environmental basis of normal and abnormal biological function, from human genes that make some people more sensitive to the adverse effects of low doses of radiation to the biochemical capabilities of complex microbial communities that could be used to produce clean energy, clean up or stabilize wastes *in situ* to minimize risks to humans and the environment, or sequester excess atmospheric carbon dioxide. Scientific tools and resources are developed and made widely available for determining protein structures at DOE synchrotron and neutron sources, for high-throughput genetic studies using mice, and for high-throughput genomic DNA sequencing. New capabilities are developed in the Genomics: GTL program for understanding the structure, function, and regulation of multi-protein complexes from DOE-relevant organisms and of complex, DOE-relevant microbial communities – information that can then be used to develop biotechnological solutions for DOE needs.

Supporting Information

BER Life Sciences supports research in the following areas:

- biological effects of low doses of ionizing radiation. The program works closely with scientists, regulators, and the public to ensure that the research results are available to develop a better scientific basis for adequately protecting people from the adverse effects of ionizing radiation.

- Genomics: GTL research, developing, together with the Advanced Scientific Computing Research program, experimental and computational resources, tools, and technologies to understand the complex behavior of biological systems – from single microbes to communities of multiple microbial species. This information can be used to develop innovative biotechnology solutions for energy production, waste cleanup, and carbon management.
- a high-throughput DNA sequencing user resource to meet DNA sequencing needs of the scientific community.
- resources, tools, and technologies to understand the function of human genes identified as part of the International Human Genome Project using model organisms such as the mouse.

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

FY 2004 Accomplishments

The Institute for Genomic Research Partners Complete Sequence of Corrosive Bacterium Desulfovibrio Vulgaris. A team of scientists led by the Institute for Genomic Research (TIGR) has sequenced the genome of Desulfovibrio vulgaris, a sulfate-reducing bacterium that can damage oil and natural gas pipelines and corrode oilfield equipment. The microbe takes part in a process called microbially influenced corrosion (MIC), in which bacteria act together to create a biofilm that covers metal pipelines or equipment by reducing sulfate to hydrogen sulfide which reacts with metals to produce metal sulfide corrosion products. MIC has caused "staggering" economic losses at industrial sites around the world, according to TIGR. It is expected that analysis of the microbe's genes will help minimize such damage. In their analysis of the D. vulgaris genome, scientists found a network of c-type cytochromes—proteins that facilitate electron transfer and metal reduction during energy metabolism and are thought to give the organism a significant capacity for reducing metals. The organism could be used to help remediate metallic pollutants such as uranium and chromium. In addition to TIGR, the sequencing team included scientists from the University of Calgary, the University of Missouri-Columbia, Johns Hopkins University, and George Washington University Medical Center. The study, funded by the U.S. Department of Energy Microbial Genome Program, was published in the May 2004 issue of Nature Biotechnology.

New Resource for Understanding Human Gene Function. The completion of the human genome sequence gave us a commonly accepted parts list of all human genes, the instructions for making proteins, the principle structural and functional molecules of life. With the completion of the human DNA sequence, a massive international effort (partially funded by the DOE Human Genome Program) was begun in August 2002 to annotate (characterize or describe) these putative genes. Over 41,000 full length DNA copies, so-called cDNAs, of the messenger RNA molecules that are the intermediate information molecules between a DNA sequence and the production of a protein were analyzed. This Full Length cDNA Annotation Jamboree involved over 100 biologists and computer scientists was initially hosted by the Japan Bioinformatics Research Center in Tokyo and has continued for the past two years. The results will be made publicly available online at http://www.publiclibraryofscience.org/. This effort was coordinated by the Integrated Molecular Analysis of Genome Expression (IMAGE) consortium, http://image.llnl.gov/, a project initiated by the DOE Human Genome Program and now funded by the National Institutes of Health. This remarkable new resource will speed discovery of gene function.

Premature Aging Caused by Low Telomerase Levels - Telomerase is an enzyme catalyzing critical steps in the replication of the exceptional chromosome tip structures, the telomeres. Telomeres require a replication mechanism distinct from that of the rest the chromosome, being comprised of multiple linear copies of a short DNA sequence. Telomeres progressively shorten over a life span, eventually limiting chromosome and cell replication. This is thought to be one of the several defenses against tumors and cancer. In the June issue of Molecular and Cellular Biology, an ORNL team describes a new protein component of the telomerase complex. The ORNL team with collaborators at the University of Toronto explored effects of exceptionally low levels of telomerase, which was genetically engineered into the mouse. In the April issue of Proceedings of the National Academy of Sciences, they report that low telomerase mice suffer premature aging effects, and so mimic a known human inherited disorder that causes premature aging. Thus a physiological balancing becomes evident, i.e., too much telomerase activity in the adult may increase the risk of cancer, while too little promotes too rapid aging. This insight is one of many achieved by the ORNL researchers over the years, using the mouse as a model for inherited genetic diseases.

Science Publishes the Genome Sequence of Geobacter, a Microbe that Precipitates Radionuclides and Metals. The genome sequence of the bacterium Geobacter sulfurreducens was published in the December 12 issue of the journal Science. The genetic code of this tiny microorganism may hold the answers to some of DOE's most difficult cleanup problems and for generating power through bio-based energy sources. The collaborative research by scientists at the University of Massachusetts and The Institute for Genomic Research (TIGR) was supported by the BER program. Geobacter microbes are commonly found in contaminated subsurface environments. These bacteria can precipitate a wide range of radionuclides and metals (including uranium, technetium, chromium, and even gold) from groundwater, thus removing contaminants from the aqueous phase and reducing risk to humans and the environment. The genome codes for all the biochemical "parts" from which Geobacter cells are built, and this knowledge should allow researchers to harness the catalytic power of this microbe in a process known as bioremediation. Geobacter is also of strong interest to the DOE because of its ability to create an electrical current in a "bio-battery". The genome sequence revealed over 100 genes that encode for c-type cytochrome proteins that facilitate electron transfer and metal reduction. Genome data also showed that Geobacter can sense and move toward metallic substances. The genome sequence and the additional research that it makes possible will lead to new strategies and biotechnologies for cleaning up metal and radionuclide-contaminated groundwater at DOE sites and for generating energy.

Protein Crystallography with Neutrons Analyzes Industrial Enzyme. The three-dimensional structures of large biological molecules such as proteins often are determined by crystallography with x-rays. Now research has demonstrated that crystallography with neutrons can reveal important structural information that cannot be found using x-rays. A newly-opened experimental station for crystallography at the Los Alamos Neutron Science Center (LANSCE) was used to determine the precise arrangement of hydrogen atoms at the active site of the enzyme D-xylose isomerase. This enzyme is used commercially to convert glucose into fructose for the manufacture of high-fructose corn syrup, a widely used sweetener in foods and beverages. The LANSCE data enabled pin-pointing the location of the hydrogen atoms of the enzyme that interact with glucose during the process. The results of the demonstration study have been published in Acta Crystallographica and a feature article about the new station has appeared in Physics Today.

X-Ray Microscopy Becomes a National Research Resource. X-rays are more energetic than visible light and thus have a shorter wavelength. This offers the possibility of using x-rays to image features in cells that are too small to be seen using optical microscopy and cannot be visualized by other types of imaging. This potential has now been realized with the initiation in April 2004 of the Resource for X-ray Tomography of Whole Cells at the Advanced Light Source (ALS) at the Berkeley Lab with joint funding by NIH and DOE. The resource will enable biologists from around the country to study sub-cellular structures in bacteria as well as human cells. The x-rays will provide pictures of the organization of essential components of the cells, pictures that will lead to better understanding of functions relevant to environmental, energy, and medical research.

Structural Biology Beamline Upgrades Work Flawlessly at New Synchrotron Ring. The storage ring at the Stanford Synchrotron Radiation Laboratory was completely replaced and recommissioned from April 2003 to March 2004 (the SPEAR3 project). The new ring emits x-ray beams that are many times more intense than those of the previous ring. This places great demands on the performance and reliability of all the experimental instrumentation using the beams. In anticipation of SPEAR3, the beamlines for structural biology were upgraded in the period 2000–2004 to meet the new requirements. They were among the first to go into service as the new ring began operation early in 2004, and have given consistently excellent results.

New DNA Sequencing User Resource for the Scientific Community. The remarkable DNA sequencing capabilities that have become available in recent years because of the success of the Human Genome Project have revolutionized the way that biologists think about and carry out their research. However, the power and value of DNA sequence information has also resulted in a demand for genomic sequencing far exceeding the remarkable capacity that is available. Now scientists have a resource that they can use on a competitive, merit-reviewed basis, to determine the DNA sequence of organisms of scientific interest and value, at no cost to the scientists. The Department’s high-throughput DNA sequencing facility, the JGI, has established a Community Sequencing Program which is providing, as a user resource, high-throughput DNA sequencing to the scientific community.

Synthetic Genome. DOE-funded researchers at the Institute for Biological Energy Alternatives (IBEA) have achieved a significant scientific advance in their efforts to piece together DNA strands, thereby helping develop new, biological methods to capture carbon dioxide from the atmosphere, produce hydrogen and clean the environment. IBEA scientists have assembled more than 5,000 bases or building blocks of DNA to create a small artificial virus, a so-called bacteriophage that infects bacteria but not humans. The researchers accomplished this in 14 days, from start to finish, reducing the time required to synthesize such a microbe from many months, even years to days. This advance brings us closer to being able to create entire microbes that are 100 to 1,000-times larger than the artificial virus created so far speeding our ability to design microbes living within the emission-control system of a coal-fired plant, consuming its pollution and its carbon dioxide, or employing microbes to radically reduce water pollution or to reduce the toxic effects of radioactive waste.

Sargasso Sea Sequencing & Discovery. Department of Energy-funded researchers at the Institute for Biological Energy Alternatives (IBEA) have sequenced DNA from Sargasso Sea samples and have discovered at least 1,800 new microbial species and more than 1.2 million new genes. IBEA researchers’ discoveries include 782 new rhodopsin-like photoreceptor genes (only a few dozen have been characterized in microorganisms to date). These new discoveries in environmental genomics lead the way to the development of new biotechnology approaches to use microbial capabilities to address DOE energy and environmental needs.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Structural Biology	**23,863**	**21,892**	**15,300**
▪ **Basic Research**	**8,563**	**6,592**	**0**

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

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

BER develops and supports access to beam lines and instrumentation at DOE's national user facilities for the Nation's structural biologists. BER coordinates, with the NIH and the NSF, the management of experimental stations at DOE synchrotrons (Advanced Photon Source, Advanced Light Source (ALS), Stanford Synchrotron Radiation Laboratory (SSRL) and National Synchrotron Light Source) and neutron beam sources (the Los Alamos Neutron Science Center (LANSCE) and High Flux Isotope Reactor (HFIR) at ORNL). User statistics for all BER structural biology user facilities are included in the BES facility user reports. A new high performance station for small angle neutron scattering is expected to become operational at HFIR in FY 2006, as is a beamline for x-ray microscopy at the ALS. DOE investment in structural biology facilities has a large impact on basic research investments made by other agencies. DOE investments in structural biology user facilities at synchrotron light sources and at the EMSL enabled the National Institute of General Medical Sciences at the NIH to make a large investment for NIH's Protein Structure Initiative to develop and apply high-throughput methods for determining protein structure. BER also continually assesses the quality of the instrumentation at its experimental stations and supports upgrades to install the most effective instrumentation for taking full advantage of the facility capabilities as they are improved by DOE.

Molecular and Cellular Biology	**102,955**	**100,768**	**111,809**
▪ **Microbial Genomics**	**9,404**	**9,747**	**0**

Microbial genomics as a separate research activity is terminated to consolidate all microbial research within Genomics: GTL. Microbial genomics research that is terminated included research on functional characterization of multi-protein complexes, improved methods for microbial genome annotation, and methods to characterize microbial consortia, all research areas now being funded as part of Genomics: GTL.

▪ **Carbon Sequestration Research**	**7,004**	**5,961**	**7,127**

Microbes and plants play substantial roles in the global cycling of carbon through the environment. Carbon sequestration research seeks to understand how plants, and the microbes that enable them to grow, work together to sequester atmospheric carbon dioxide. In FY 2006 the program continues to leverage the genomic DNA sequence of the poplar tree, completed in FY 2004, by developing high-throughput experimental and computational methods for understanding the poplar genome and proteome, especially related to carbon utilization.

	FY 2004	FY 2005	FY 2006
(dollars in thousands)			

Research will also focus on microbes that live in the poplar rhizosphere (root zone) with the intent of understanding the role that these microbes play in the transfer of carbon between the roots and the soil. The program will emphasize organisms and pathways that serve to increase long-term carbon storage over organisms and pathways that decrease carbon storage. A goal is to identify strategies that would lead to increased carbon storage in the poplar rhizosphere and surrounding soil, such as manipulation of the soil chemical environment to promote certain microorganisms or particular metabolic pathways. This research leverages BER's more fundamental microbial systems biology research in Genomics: GTL and BER's terrestrial carbon cycle research to evaluate options for molecular-based terrestrial carbon sequestration. Research also focuses on microbial based strategies for hydrogen production, part of a broad strategy to reduce carbon emissions.

	FY 2004	FY 2005	FY 2006
▪ **Genomics: GTL**	**68,727**	**67,564**	**87,186**

Genomics: GTL is a microbe-based program at the forefront of the biological revolution - a systems approach to biology at the interfaces of the biological, physical, and computational sciences. It will take advantage of solutions that nature has already devised to solve many of DOE's most pressing and expensive problems. Genomics: GTL offers the possibility of biotechnology solutions that can give us abundant sources of clean energy yet control greenhouse gases such as carbon dioxide, a key factor in global climate change, and that can help us clean up contamination of the environment.

Genomics: GTL is a comprehensive, systems-level, interdisciplinary research program that will require development of novel capabilities for new high-throughput biological research, e.g., for protein production, molecular imaging, small molecule production, and proteomics. It will involve a well integrated mix of experimental and computational science that will enable us to predict responses of biological systems to their environments and to use that capability to address DOE and national challenges.

Over the long-term, Genomics: GTL will support a combination of:

- fundamental research and technology development;
- development and use of scientific user facilities that will implement much of this new research and technology in high-throughput biological research user facilities much like DNA sequencing was moved from the research laboratory to sequencing facilities in the human genome project; and
- demonstration projects developed in partnership with other DOE offices such as Energy Efficiency and Renewable Energy, Fossil Energy, and Environmental Management to "field test" potential biotechnology solutions for clean energy production, reducing carbon dioxide in the atmosphere, and cleanup of the environment.

BER is developing a procurement strategy for the selection of Genomics: GTL facilities that will allow universities and other entities to compete with DOE national laboratories.

Nature has created a remarkable array of multi-protein molecular machines and complex microbial community structures with exquisitely diverse, precise, and efficient functions and controls. The goal of Genomics: GTL is to understand the nature and control of these molecular machines and of complex microbial communities so well that we can use and even redesign them to address DOE and national needs. Success in Genomics: GTL will be measured by scientific breakthroughs that lead to predictive computational models for:

- molecular machines and other molecules that work together in microbes,
- complex networks that control the assembly and operation of these machines, and
- the structure and biochemical capabilities of complex microbial communities.

The overriding goal of this long-term research program is to understand biology well enough to be able to predict the behavior and responses of biological systems – from cells to organisms so that they can best be used to develop biotechnology solutions that address DOE mission needs in energy, the environment, and national security. This research will lead to greatly improved computational strategies, tools, and resources that are central to the success of Genomics: GTL and, indeed, to all of biology, and that will be developed in partnership with the Advanced Scientific Computing Research program.

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

In FY 2006, the program continues to support a mix of large multidisciplinary research teams and smaller individual investigator projects to:

- characterize and develop computational models to describe the biochemical capabilities of microbial communities;
- develop high-throughput approaches for isolating and characterizing microbial molecular machines;
- develop computational models that accurately describe and predict the behavior of genetic regulatory networks;
- develop new technologies and strategies for imaging individual proteins and molecular machines inside microbes;
- develop new technologies for producing large numbers of microbial proteins and molecular tags to identify those proteins; and
- determine the societal and legal implications of genomics research and technology.

In FY 2006, research will also continue the high-throughput DNA sequencing of microbes and microbial communities. This DNA sequence information will continue to serve as the core of biological information needed to understand the control and function of molecular machines and complex microbial communities.

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

	FY 2004	FY 2005	FY 2006
▪ **Low Dose Radiation Research**	**17,820**	**17,496**	**17,496**

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

BER will continue to emphasize research that leads to a molecular level understanding of the biological effects of low doses of radiation exposure and the characterization of individual genetic susceptibility to radiation.

In FY 2006, BER will continue to emphasize the development and use of experimental *in vivo* systems that are more relevant to human risk from exposure to low doses of radiation. Only by understanding the effects of low doses of radiation in intact tissues or organisms can we hope to determine the health risks from those exposures.

BER will continue its emphasis on research that results from productive linkages between experimentalists and risk modelers, a relationship that lies at the critical interface between experimental science, risk analysis, and development of better risk management policies.

In particular, research will focus on:

- *Bystander effects* – the responses of cells that are not directly traversed by radiation but that respond with gene induction and/or production of potential genetic and carcinogenic changes. It is important to know if bystander effects can be induced by exposure to low linear energy transfer (LET) radiation delivered at low total doses or dose-rates. This bystander effect potentially "amplifies" the biological effects (and the effective radiation dose) of a low dose exposure by effectively increasing the number of cells that experience adverse effects to a number greater than the number of cells directly exposed to radiation. Scientists will be challenged to determine if bystander effects to low doses of ionizing radiation occur *in vivo*.

- *Genomic instability* – the loss of genetic stability, a key event in the development of cancer, is induced by radiation and expressed as genetic damage that occurs many cell divisions after the insult is administered. Current evidence indicates that DNA repair and processing of radiation damage can lead to instability in the progeny of irradiated cells. There is also evidence suggesting that individual susceptibility to genomic instability is under genetic control. However, there is virtually no information on the underlying mechanisms. The role of genomic instability in radiation-induced cancer remains to be determined experimentally.

It is also important to determine if genomic instability occurs at low total doses (<10 rads) or low dose rates. Scientists will be challenged to determine the extent to which low doses of radiation induce genomic instability *in vivo*.

- *Adaptive response* – the ability of a low dose of radiation to induce cellular changes that reduce the level of subsequent radiation-induced or spontaneous damage. If low doses of radiation regularly and predictably induce a protective response in cells to subsequent low doses of radiation or to spontaneous damage, this could have a substantial impact on estimates of adverse health risk from low dose radiation. The generality and the extent of this apparent adaptive response needs to be further investigated in *in vivo* systems.
- *Genetic factors that affect individual susceptibility to low dose radiation* – Research is also focused on determining whether genetic differences make some individuals more sensitive to radiation-induced damage since these differences could result in individuals or sub-populations that are at increased risk for radiation-induced cancer.
- *Mechanistic and risk models* – Novel research is supported that involves innovative collaborations between experimentalists and modelers to model the mechanisms of key radiation-induced biological responses and to describe or identify strategies for developing biologically based risk models that incorporate information on mechanisms of radiation-induced biological responses. This has been the most difficult and challenging component of the program. A comprehensive effort is underway to identify innovative new research strategies that will determine the extent to which the development of biologically based risk models for low dose radiation is possible. This will involve interactions between experimental and computational scientists and with scientists at regulatory agencies responsible for developing risk policy.

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

	FY 2004	FY 2005	FY 2006
Human Genome	**63,578**	**64,572**	**64,226**
▪ **Joint Genome Institute**	**53,453**	**51,500**	**51,500**

Although research to understand the genes identified in the Human Genome Project continues, the Joint Genome Institute's (JGI) high-throughput DNA sequencing factory, the Production Genomics Facility, has transitioned away from human DNA sequencing to help meet the growing demand for DNA sequencing in the broader scientific community. The JGI has established a Community Sequencing Program (CSP) that devotes 60% of its sequencing capacity to the merit-reviewed sequencing needs of the broader scientific community, including the needs of other agencies. DNA sequencing targets are being chosen using a process of peer review of requests for sequencing submitted by individual scientists and other federal agencies. In FY 2006, the CSP will sequence approximately 20 billion base pairs of DNA from individual

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

microbes, microbial communities, small plants and animals, and large plants and animals that will be selected by the CSP's merit review panel in FY 2005. Any large genomes selected for sequencing through the CSP will be required to meet the additional criteria of general relevance to DOE mission needs. Forty percent of the JGI's DNA sequencing capacity is being used to address DOE sequencing needs, including BER programs such as carbon sequestration research and bioremediation research, and other DOE and national needs. The substantial high-throughput DNA sequencing needs of the GTL program are supported at the JGI directly by the Genomics: GTL program and are not included here in funds for the JGI.

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

	FY 2004	FY 2005	FY 2006
▪ **Tools for DNA Sequencing and Sequence Analysis**	**8,000**	**11,225**	**11,126**

BER continues to develop the tools and resources needed by the scientific, medical, and industrial sector communities to fully exploit the information contained in complete DNA sequences, including the first human genome sequence. Unimaginable amounts of DNA sequencing, at dramatically increased speed and reduced cost, will still be required in the future for medical and commercial purposes and to understand the information in the DNA sequence that has already been determined. BER continues to further improve the efficiency and cost effectiveness of its own DNA sequencing factory at the JGI by improving the reagents used in DNA sequencing and analysis (including genome assembly and annotation); decreasing the costs of sequencing; increasing the speed of DNA sequencing; and developing more robust computational tools for genome-wide data analysis.

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

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

	FY 2004	FY 2005	FY 2006
▪ **Ethical, Legal, and Societal Issues (ELSI)**	**2,125**	**1,847**	**1,600**

The completion of the International Human Genome Project and the transition of BER's Human Genome research program from a human DNA sequencing program to a DNA sequencing user resource for the scientific community that focuses on the sequencing of scientifically important microbes, plants, and animals brings BER's Human Genome ELSI program to an end. In FY 2006, research will include activities applicable to Office of Science issues in biotechnology and nanotechnology such as environmental or human health concerns associated with Genomics: GTL or nanotechnology research. Research with these funds will be coordinated across the Office of Science.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Health Effects	**9,924**	**10,237**	**7,321**
▪ **Functional Genomics Research**	**9,924**	**10,237**	**7,321**

Understanding the structure and function of the human genome. – Many individual genes and the regulatory networks that control them have been conserved during evolution in organisms as diverse as yeast and humans. Thus, model organisms including *Fugu* (puffer fish), *Ciona* (sea squirt), frog, and mouse can be used to efficiently understand the organization, regulation, and function of much of the human genome. Functional genomics research is a key link between human genomic sequencing, which provides a complete parts list for the human genome, and the development of information (a high-tech owner's manual) that is useful in understanding normal human development and disease processes. The mouse continues to be a major focus of our efforts and is an integral part of our functional genomics research program. Research at BER's newest user facility, the Center for Comparative and Functional Genomics at Oak Ridge National Laboratory serves as a national focal point for high-throughput genetic studies using mice. This facility creates and genetically characterizes new mutant strains of mice that serve as important models of human genetic diseases and for understanding gene function especially as they relate to the genetic information found on human chromosomes 5, 16, and 19 (DOE's chromosomes in the International Human Genome Project). It also develops high-throughput tools and strategies to characterize these mutant strains of mice. This mouse genetics research provides tools useful to the entire scientific community for decoding the functionality of the human genome as human DNA sequence becomes available.

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

	FY 2004	FY 2005	FY 2006
SBIR/STTR	**0**	**5,367**	**5,379**

In FY 2004 $4,958,000 and $598,000 were transferred to the SBIR and STTR programs, respectively. FY 2005 and FY 2006 amounts are the estimated requirements for continuation of these programs.

	FY 2004	FY 2005	FY 2006
Total, Life Sciences	**200,320**	**202,836**	**204,035**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Structural Biology	
▪ Structural Biology research is reduced to support high-relevance, higher priority research on Genomics: GTL. Components that support characterization of multi-protein complexes will be funded under Genomics: GTL. Research will not be funded on the characterization of proteins and multi-protein complexes involved in DNA repair and the bioremediation of metals and radionuclides.	-6,592

	FY 2006 vs. FY 2005 ($000)
Molecular and Cellular Biology	
▪ Microbial Genomics research is phased out to support high-relevance, higher priority research that addresses the previously described goals of Genomics: GTL. Microbial research that will no longer be funded includes: (1) the development of improved and high-throughput approaches to functional characterization (e.g., transporters, environmental sensors, redox enzymes, cytoskeletal components, DNA repair systems, metal reductases, biodegradative enzymes, etc.) of microbial multi-protein complexes, (2) novel computational tools to increase the value of microbial genome sequence information, and (3) computational analyses to support existing techniques that would enable the more efficient finishing of draft sequences of microbial genomes.	-9,747
▪ Carbon Sequestration Research is restored to the FY 2004 level to use the poplar tree and/or microbial genomic sequences to enhance the partitioning of substantial amounts of carbon into components of trees or soil organic matter to develop methods for long term carbon sequestration.	+1,166
▪ Genomics: GTL is increased to support high-relevance, higher priority research to develop new methods to image molecular machines inside microbes, to alter the biochemical properties of complex microbial communities, to determine the proteome of complex microbial communities, to identify changes that cells make to its proteins once they are produced and to develop new methods for determining the sequence of a DNA molecule when starting with only one copy of the molecule, e.g., starting with only one microbial cell.	+19,622
Total Molecular and Cellular Biology	**+11,041**
Human Genome	
▪ Human Genome research is supported at near FY 2005 levels. Ethical, Legal, and Societal Issues Research will focus on issues in biotechnology and nanotechnology in cooperation with other programs in the Office of Science, such as environmental or human health concerns associated with Genomics: GTL or nanotechnology research	-346
Health Effects	
▪ Health Effects research is reduced to support high relevance, higher priority research on Genomics: GTL. Funding will be reduced for research to develop high relevance experimental models to understand the function and regulation of genes important in biological responses to injury, such as radiation damage, that provide an interface between unrealistic but commonly used two-dimensional cell culture models and research using experimental animals.	-2,916

	FY 2006 vs. FY 2005 ($000)
SBIR/STTR	
▪ Increases in SBIR/STTR due to increases in Life Sciences research funding	+12
Total Funding Change, Life Sciences	**+1,199**

Climate Change Research

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Climate Change Research					
Climate and Hydrology	75,603	74,420	76,148	+1,728	+2.3%
Atmospheric Chemistry and Carbon Cycle	38,474	35,779	36,120	+341	+0.9%
Ecological Processes	15,847	18,729	18,726	-3	0.0%
Human Interaction	8,073	8,149	8,071	-78	-0.9%
SBIR/STTR	0	3,917	3,894	-23	-0.6%
Total, Climate Change Research	137,997	140,994	142,959	+1,965	+1.4%

Description

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

Benefits

This subprogram's research will reduce and resolve key uncertainties and provide the scientific foundation needed to predict, assess, and mitigate adverse effects of energy production and use on the environment through research in climate modeling and simulation, climate processes, carbon cycle and carbon sequestration, atmospheric chemistry, and ecological science.

Supporting Information

The Climate Change Research subprogram supports four contributing areas of research: Climate and Hydrology; Atmospheric Chemistry and Carbon Cycle; Ecological Processes; and Human Interactions. The research is focused on understanding the physical, chemical, and biological processes affecting the Earth's atmosphere, land, and oceans and how these processes may be affected, either directly or indirectly, by energy production and use, primarily the emission of carbon dioxide from fossil fuel combustion. BER has designed and planned the research program to provide the data that will enable objective assessments of the potential for, and consequences of, global warming. It is intended to provide a scientific basis that will enable decision makers to determine a "safe level" of greenhouse gases in the Earth's atmosphere to avoid a disruptive, human-induced, climate change.

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 President Bush in 1989 and codified by Congress in the Global Change Research Act of 1990 (P.L. 101-606), and the current Administration's Climate Change Research Initiative (CCRI).

The BER Climate Change Research subprogram (excluding the carbon sequestration element of Atmospheric Chemistry and Carbon Cycle) represents DOE's contribution to the CCSP (USGCRP and

CCRI). The carbon sequestration element plus carbon sequestration activity in the Life Sciences subprogram are BER’s contribution to the CCTP.

The CCRI is a set of cross-agency programs in areas of high priority climate change research where substantial progress is anticipated over the next three to five years. The specific focus areas include climate forcing (atmospheric concentrations of greenhouse gases and aerosols); climate feedbacks and sensitivity; climate modeling, including enabling research; regional impacts of climate change, including environment-society interactions; and climate observations. In FY 2006, BER will continue to participate in one of the specific research areas: climate forcing, which includes modeling carbon sources and sinks, especially those in North America. In FY 2006 BER will continue to support research to quantify the magnitude and location of the North American carbon sink, a high priority need identified in the interagency Carbon Cycle Science Plan, and on climate modeling, Atmospheric Radiation Measurement (ARM), and Integrated Assessment activities (BER’s FY 2006 CCRI request is $26,924,000).

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

BER’s Climate Modeling program develops advanced, fully coupled, atmosphere-ocean-sea ice-land surface climate models and uses premier supercomputers to simulate and predict climate and climate change, including evaluating uncertainties in climate models due to changes in atmospheric levels of greenhouse gases on decade-to-century time scales.

The Atmospheric Science program was reconfigured in FY 2005 to focus on acquiring the data needed to understand the atmospheric processes that control the transport, transformation, and fate of energy-related aerosols emitted to the atmosphere and their radiative properties that affect climate. In FY 2006, the program will continue studies of the direct and indirect effects of aerosols on climate.

Research on the carbon cycle explores the movement of carbon on a global scale starting from natural and anthropogenic emissions to ultimate sinks in the terrestrial biosphere and the oceans. Experimental and modeling efforts primarily address the net exchange of carbon between major types of terrestrial ecosystems and the atmosphere.

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

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

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

Periodic retrospective analysis is employed to evaluate program management processes, priorities, and outcomes. A BERAC COV for the Climate Change Research Program was established in FY 2004 to provide outside expert validation of the program's merit-based review and funding decision processes that impact scientific quality, programmatic relevance, and performance. The COV found the Climate Change Research subprogram to be a credit to DOE and an example of the way that Executive agencies should operate. It also found many of the programs within the subprogram to be unique. The COV concluded that the Climate Change Research programs are productive and support high quality research that plays an important role in the DOE and especially in the interagency U.S. Climate Change Science Program. The COV found the Climate Change Research subprogram to be generally well managed, but noted the need to improve documentation of the basis for proposal funding decisions, and the performance and outcomes of Climate Change Research programs. BER has taken action to address these findings.

The full report and the BER response is available on the BER web site (http://www.science.doe.gov/ober/berac.html).

FY 2004 Accomplishments

Climate Model Software Improvements Double Performance. BER climate model software engineering, as part of the Scientific Discovery through Advanced Computing (SciDAC) program, markedly improved the performance of global climate models. Through a combination of an improved computer algorithm for inter-node communication on parallel processing computers and optimization of the numerical algorithms in the code of the atmospheric dynamical core and land surface submodels, the throughput (simulated years per day of computer time) of the Community Atmosphere Model (CAM), the atmospheric component of the Community Climate System Model (CCSM), was doubled. In addition, the new inter-node communications algorithm dramatically increased scalability, enabling the model to run more efficiently on computers with larger numbers of processors. These, and other BER improvements to climate model software (with a focus on the CCSM) are causing significant gains in throughput, and hence to the science accomplished with climate models.

New Cloud Submodel Improves General Circulation Model (GCM) Simulations. An evaluation of adding a so-called ARM "convective trigger" submodel to the National Center for Atmospheric Research (NCAR) Community Atmosphere Model (CAM2) showed that the added submodel resulted in significant improvements of CAM model simulations of global precipitation, high clouds, and zonally-averaged atmospheric temperature and moisture fields. Addition of the convective trigger submodel also resulted in a reduction of more than 50% in the simulated underestimate of tropospheric humidity compared to that predicted by the CAM2 model without the convective trigger.

New Diagnostic for Evaluating Climate Model Performance. A new model diagnostic, referred to as the Broadband Heating Rate Profile (BBHRP) was developed that helps reduce a significant obstacle to improving the predictive accuracy of climate models - the ability to accurately quantify the interaction of the clouds, aerosols, and gases in the atmosphere with radiation. The BBHRP, which is based on a fusion of detailed field measurements from the ARM program, provides a realistic estimate of the impact of clouds, aerosols, and greenhouse gases on radiative heating or cooling. Since direct observation of these interactions is extremely difficult, this diagnostic can be directly compared to the model-predicted impacts, thus enabling model uncertainties to be evaluated.

New Techniques Reduce Water Vapor Measurement Uncertainties. Researchers from the ARM program reduced the uncertainty of measurements of water vapor in the atmosphere from greater than 25% to less than 3%. Achieving the improved accuracy was done by using more accurate instruments, measurements using a microwave radiometer and a Raman lidar coupled with instrument intercomparisons, and validation of algorithms used to convert instrumental data to estimates of water vapor content. Because water vapor is by far the most abundant of the greenhouse gases, accurate water vapor measurements are essential for understanding atmospheric processes and accurately representing them in climate models.

Net Carbon Gain of Forests, Grasslands, Agricultural Crop Systems, and Tundra is Measured. AmeriFlux data from 37 terrestrial sites, including forest, grassland, agricultural crop, and tundra sites showed that the ratio of annual ecosystem respiration to gross photosynthesis averaged 0.83. The carbon that is re-emitted back to the atmosphere includes fluxes from respiration of living vegetation and the microbial decomposition of soil carbon. These results indicate that of the total amount of carbon assimilated in gross photosynthesis, an average of about 17% is retained in living biomass and soil components of the mostly forested ecosystems that have been measured. It is believed that a relatively small but yet unmeasured quantity of the retained carbon may also be lost from these systems by runoff to rivers or by carbon transport through the soil profile. Most of the measured sites represent developing or mature forests, so the percentage of carbon retained would likely be lower with young regenerating forest stands following disturbance by logging or wildfire. The results on net carbon gain by forests reported by the BER-funded researchers were recognized as an outstanding scientific contribution, and received a monetary award from the World Meteorological Organization in 2004.

Iron Input to Southern Ocean Affects Carbon Sequestration. The Southern Ocean Iron Experiment (SOFeX) (jointly funded by BER and NSF) tested the hypothesis that adding iron to the Southern Ocean would cause phytoplankton blooms that could increase uptake of carbon dioxide and the subsequent flux of carbon to the deep ocean was experimentally tested. Iron was added to two square patches of the Southern Pacific, 15 kilometers on a side, in order to increase iron levels about 100 times over the ambient conditions. The iron additions caused large phytoplankton blooms, which were visible in satellite images of the ocean. Each bloom consumed large amounts of atmospheric carbon dioxide, and some of that carbon fixed in the mixed surface layers sank to hundreds of meters in depth. This is important because long-term storage of atmospheric carbon in the ocean requires that it sink to the deep ocean where it is likely to remain for long periods of time. Carbon that remains near the surface is likely to be rapidly released back to the atmosphere. The results indicate that large-scale carbon sequestration would be possible through iron fertilization of the ocean. When compared to the rates of carbon released to the atmosphere globally from human activities, the flux of carbon to the deep ocean resulting from the iron fertilization experiment was relatively small. With the low carbon export efficiency of added iron (the ratio of carbon sequestered to iron added), the results indicate that iron fertilization as a strategy for mitigating the increase in atmospheric carbon dioxide would have to be done continuously over large areas of the ocean to have a significant impact on atmospheric carbon dioxide levels. Furthermore, the environmental effects of such a strategy on ocean biology, ecology, and chemistry are unknown.

Soil Restoration is a Significant Sink for Carbon Dioxide. Managing the organic matter (OM) content of cultivated soils is a recognized agricultural practice for sustaining soil quality and fertility. A novel (chronosequence) research approach was used to measure changes in soil organic matter over time under different land use types at the Fermilab National Environmental Research Park in northeastern Illinois. The results demonstrated that converting degraded agricultural soils to prairie ecosystems represents an important approach for enhancing soil carbon sequestration. When this practice was followed for a 23-year period, the rate of sustained soil carbon accrual was ½ metric tonne per hectacre per year. Further, by comparing agricultural soils to the near-equilibrium OM levels of native prairie remnants, the study found that Fermilab soils, which are typical of the Corn Belt Region, have a carbon storage potential of about 60 metric tonnes per hectacre. The data suggest that 50% of the potential soil carbon sink of native prairie would be achieved within 50 years if agricultural lands in the Corn Belt Region were allowed to return to native prairie.

Long-term Field Research Documents Potential Effects of Increasing Atmospheric Carbon Dioxide and Ozone on Forest Growth. BER constructed, maintains, and operates a large-scale field research facility in northern Wisconsin to study effects of experimentally elevated concentrations of carbon dioxide and ozone on growth of hardwood forests since concentrations of both carbon dioxide and ozone are increasing as by-products of energy production from fossil fuels. The forest being studied, a constructed mixture of aspen, birch, and maple trees has been fumigated with carbon dioxide and ozone since 1997. As expected, elevated carbon dioxide concentration enhanced tree growth, but for aspen, elevated ozone has counteracted the beneficial effects of carbon dioxide. For the first five years of the experiment, elevated ozone did not affect maple growth, but beginning in 2002, maple growth has slowed with elevated ozone. This latter result highlights the importance of long-term ecological research; longer-term forest responses to environmental change may only become apparent after several years in an altered environment.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Climate and Hydrology	**75,603**	**74,420**	**76,148**
▪ **Climate Modeling**..	**28,377**	**27,076**	**27,141**

Model-based climate prediction provides the most scientifically valid way of predicting the impact of human activities on climate for decades to centuries in the future. BER will continue to develop, improve, evaluate, and apply the best coupled atmosphere-ocean general circulation models (GCMs) that simulate climate variability and climate change over these time scales. The goal is to achieve statistically accurate forecasts of future climate over regions as small as river basins using ensembles of model simulations. The ensembles will accurately incorporate the dynamic and thermodynamic feedback processes that influence climate, including clouds, aerosols, and greenhouse gas forcing. Current predictions are limited by computational resources and uncertainties in the model representations of key small-scale physical processes, especially those involving clouds, evaporation, precipitation, and surface energy exchange. BER will address both the computational and scientific shortcomings through an integrated effort. Support will continue to provide climate modelers access to the high-end computational resources needed to complete ensembles of climate simulations using present and future models. BER will emphasize research to develop and employ information technologies that can quickly and efficiently work with large and distributed data sets of both observations and model predictions to produce quantitative information suitable for the study of regional climate changes. BER will continue to fund the multi-institutional research consortia established in FY 2001 to further the development of comprehensive coupled GCMs for climate prediction that are of higher resolution and contain accurate and verified representations of clouds and other important climate processes. In FY 2006, BER will continue the partnership with the Advanced Scientific Computing Research program. This includes applying the computing resources for climate simulation and continuing climate model development efficiently across a wide variety of computing platforms. Additionally, BER will emphasize data assimilation methods so as to quickly make use of the high-quality observational data streams provided by ARM, satellite, and other USGCRP climate data programs to evaluate model performance.

In FY 2006, BER will provide important input to the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report, specifically model output for use by the IPCC Working Group I and others involved in climate change assessments. BER research will use the Community Climate System Model, version 3 (CCSM3) to produce ensembles of climate simulations based on IPCC scenarios of greenhouse gas emissions and other factors for the coming century. In FY 2006 the results of those simulations will be made available to and analyzed by researchers around the world, by storing model results at the IPCC Model Data archive maintained by the DOE Program for Climate Model Diagnosis and Intercomparison at Lawrence Livermore National Laboratory. These activities will be essential for understanding the state-of-the-science of U.S. climate modeling and uncertainties in simulating future climatic changes. BER will also continue to provide the infrastructure for evaluating the performance of major climate models and defining what changes may be needed to improve their performance. This will be done through continued support and coordination of model-data intercomparisons and the maintenance of test beds for evaluating model parameterizations.

In FY 2006, BER’s SciDAC program ($7,776,000) will focus on improving the models used for climate simulation and prediction. A dedicated effort will continue to provide a robust and extensible software engineering framework for the CCSM, a code used by hundreds of researchers on many different high-end computing platforms. Additional research will provide the prototype climate model of the future that will explore approaches to climate simulation and prediction for the next ten years.

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

High performance computing resources are provided for development and implementation of advanced climate models.

▪ **Atmospheric Radiation Measurement (ARM) Research**	**12,861**	**13,170**	**14,833**

In FY 2006, the principal goal of the ARM scientific enterprise continues to be the development of an improved understanding of the radiative transfer processes in the atmosphere and to formulate better parameterizations of these processes in climate prediction models, referred to as General Circulation Models (GCMs). ARM research supports about 50 principal investigators involved in studies of cloud physics and the interactions of solar and infrared radiation with water vapor and aerosols (including black soot). University scientists form the core of the ARM science team that networks with the broader academic community as well as with the scientists at the DOE National Laboratories and with federal scientists at NASA, NOAA, and DOD. ARM scientists pursue research as individuals and as members of teams and contribute both to the production of ARM data, e.g., as designers of cutting-edge remote sensing instrumentation, as well as consumers of the data produced at the three ARM sites. To facilitate the knowledge transfer from the ARM program to the premier modeling centers, the ARM program supports scientific “Fellows” at the NSF’s National Center for Atmospheric Research, the NOAA’s National Center for Environmental Prediction, and the European Center for Medium-Range Weather Forecasting in the U.K. In addition, a model parameterization test bed that was fully implemented in FY 2004 will be continued, to enable the testing and improvement of submodels by rapidly incorporating data from the ARM sites into the models to enable diagnostic tests and intercomparisons of model simulations with real world data.

In FY 2006, the ARM program will undertake the Tropical Warm Pool – International Cloud Experiment (TWP-ICE) near Darwin, Australia. The experiment will be a collaborative effort between the ARM program, the ARM Unmanned Aerial Vehicle (UAV), the Australian Bureau of Meteorology, NASA, the European Commission DG RTD-1.2, and several United States, Australian, Canadian and European universities. TWP-ICE is aimed at describing the properties of tropical cirrus clouds and the convection that leads to their formation. Cirrus clouds are ubiquitous in the tropics and potentially have a large impact on climate but the properties of these clouds are poorly understood. A crucial product from this experiment will be a data set suitable for both estimating the forcing resulting from cirrus clouds and testing the performance of cloud resolving models and parameterizations in GCMs. This data set will provide the necessary link between cloud properties and the models that are attempting to simulate them.

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

The enhanced research funding will accelerate development and application of 2- and 3-D cloud resolving models in atmospheric GCMs to explore the capabilities, data, and computational needs of the superparameterization approach to climate modeling.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Atmospheric Radiation Measurement (ARM) Infrastructure**	**31,441**	**31,441**	**31,441**

In FY 2006, the ARM infrastructure program will continue to develop, support, and maintain three stationary ARM Cloud Radiation Testbed (CART) facilities and associated instrumentation and a mobile ARM facility. BER will continue to operate over two hundred instruments (e.g., multifilter shadow band radiometers for aerosol measurements; Raman Lidar for aerosol and cloud measurements; radar wind profiler systems; radar cloud measurement systems; sky imaging systems; arrays of pyranometers, pyrgeometers, and pyrheliometers for atmospheric and solar radiation measurements; and standard meteorological measurement systems for characterization of the atmosphere) at the Southern Great Plains facility and will continue operations at the Tropical Western Pacific facility and the North Slope facility in Alaska. The ARM program will continue to provide data to the scientific community through the ARM Archive.

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

In conjunction with the ARM program, the UAV program will conduct a major field campaign to measure the effect of cirrus clouds on the absorption and scattering of downwelling radiation over the Western Tropical Pacific ARM-CART site.

The CCRI ARM program will continue to deploy a mobile climate observatory in a selected data-poor region (e.g., tropics) or a region that represents a location of opportunity for measuring the effects of atmospheric conditions on the radiation balance that are currently poorly understood (e.g., direct and indirect effects of aerosols). These atmospheric measurements are needed to fill data gaps and to develop the corresponding data products essential for evaluating and modeling the effects of atmospheric processes and properties on the radiation balance. The mobile climate observatory will be instrumented for cloud and radiation measurements. The primary siting criterion is to provide the measurements needed to address specific modeling needs that presently cannot be addressed by the permanent ARM sites. Activities are coordinated with other U.S. agencies and international partners, such as Australia, Japan, China, and European countries. Data products will be developed through collaborations with model developers. In FY 2006, the criteria for data products for evaluating precipitation processes will be established.

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Atmospheric Radiation Measurement (ARM)/Unmanned Aerial Vehicles (UAV)**	**2,924**	**2,733**	**2,733**

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

	FY 2004	FY 2005	FY 2006
Atmospheric Chemistry and Carbon Cycle	**38,474**	**35,779**	**36,120**
▪ **Atmospheric Science**	**14,366**	**12,751**	**12,551**

The CCSP strategic plan has raised the priority of research dealing with the climate effects of atmospheric aerosols. As a result BER restructured the Atmospheric Science program in FY 2005 to focus entirely on the aerosol-climate connection.

In FY 2006, the Atmospheric Science Program (ASP) will continue to quantify the impacts of energy-related aerosols on climate. It will continue to be closely coupled with other components of DOE's climate change research, especially the ARM program. The ASP will also continue to be broadly coordinated with the air quality and global change research communities, including collaborations with the EPA, NASA, NOAA, and with the DOE Office of Fossil Energy's Airborne Fine Particulate Matter (PM) Research program. Regional patterns of aerosol distribution will be related to sources and sinks, and the information will feed the models that simulate the impacts of aerosols on climate.

The ASP acquires data to understand the atmospheric processes that control the transport, transformation, and fate of energy-related aerosols. Emphasis will be on processes relating to particulate matter and climate change. Field and laboratory studies will continue to be conducted in atmospheric chemistry and acquired data will be used to develop and validate predictive models of aerosol properties and their effect on radiative forcing of climate. The research will include studies of chemical and physical processes affecting sulfur and nitrogen oxides, gas-to-particle conversion processes, and the deposition and resuspension of associated aerosols. It will also include studies to improve understanding of the meteorological processes that control the dispersion of energy-related chemicals and particulates in the atmosphere. Much of this effort will involve multi-agency collaboration, and university scientists will play key roles. The information is essential for assessing the effects of energy production on climate and will contribute to the evaluation of science-based options for minimizing the impact of energy production on climate change.

The ASP will conduct a major collaborative field study in FY 2006 aimed at determining the sources, chemical and physical properties, and radiative effects of aerosols derived from major urban centers. One candidate location is Mexico City, the largest megacity in North America. As part of this field study, BER will support simultaneous ground and aircraft measurements to examine the chemical composition and radiative impacts of the aerosols that are in the Mexico City plume. Another candidate location for an ASP field study in FY 2006 is Houston, Texas, where the transport and transformations of aerosols in the Houston region that affect aerosol radiative forcing of climate would be examined in collaboration with NOAA.

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Terrestrial Carbon Processes and Ocean Sciences**	**15,439**	**14,521**	**16,613**

In FY 2006, BER will continue supporting the AmeriFlux program, a network of approximately 15 research sites that measure the net exchange of CO_2, energy, and water between the atmosphere and major terrestrial ecosystems in North America. These measurements are linked to field measurement campaigns across North America that will test how well point measurements represent larger areas and allow the estimation of carbon sources and sinks on a regional basis. This research supports the interagency Carbon Cycle Science Plan. The potential for measuring fluxes of other greenhouse gases, e.g., methane and nitrous oxide, will also be added to 5 to 10 AmeriFlux sites.

BER will also continue research to refine and test terrestrial carbon cycle models based on mechanistic representations and carbon accounting. The models will be used to estimate the magnitude of potential carbon sinks and sources in response to changes in environmental factors, including climate.

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

In FY 2006, BER CCRI activities on the carbon cycle will continue to explore the movement of carbon starting from natural and human-induced emissions to the atmosphere to ultimate sinks in the terrestrial biosphere and the oceans. The AmeriFlux sites supported by BER are essential to quantifying the net exchange of carbon between the atmosphere and major terrestrial ecosystems in North America. Hence, they are essential to documenting the magnitude and variation in the North American carbon sink and how it is affected by variation and changes in environmental factors such as climate. BER will continue measurements and process studies at the network of AmeriFlux sites across North America. This information, along with data from extensive measurements around the sites, will provide a sound scientific basis for extrapolating carbon flux measurements at AmeriFlux sites to landscape and regional scales. Hence, it will improve estimates of the magnitude of the North American carbon sink and identify the regions and ecosystem types that account for the sink.

In FY 2006, BER terrestrial carbon cycle research, as a partner in the Interagency North American Carbon Program (NACP), will provide data, modeling, and analysis products from the Mid-Continental Intensive (MCI) field campaign. Data on net ecosystem exchange (NEE) of carbon dioxide will be produced by about 15 of the AmeriFlux Network sites, and these data along with research on fundamental mechanisms and processes will help to validate remote sensing observations and model calculations of terrestrial sources and sinks for this region of North America. One important outcome of the NACP-MCI field study will be a test of the suite of methodologies on atmospheric observations, flux measurement, biometric inventory, and remote sensing methodologies. The key contribution of the BER AmeriFlux Program is unique NEE and biometric data and ecosystem carbon cycle analysis.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

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

▪ **Carbon Sequestration Research**	**8,669**	**8,507**	**6,956**

In FY 2006, terrestrial carbon sequestration research will develop an improved soil carbon model based on actual measurements of carbon in extractable and well-characterized components of soil. New information on soil aggregate formation and stability factors will be incorporated into extant models like Century, EPIC, and Rothamsted, to improve actual correspondence between model algorithms and the measured components of soil carbon in laboratory and field investigations. Simulations with improved soil carbon models will be a significant step forward in the development of a methodology to evaluate the effectiveness of carbon sequestration practices because it will allow direct comparisons between modeled results and observations.

New research on microbial processes that affect carbon transformation and sequestration in terrestrial soils using technologies, capabilities, and methods developed by the Genomics: GTL program will be initiated. The new research will leverage the DNA sequence information on naturally-occurring soil microbes and will focus on applying this and other information on gene functions, regulatory pathways, and process rates of soil microbes (e.g., bacteria, fungi in the rhizosphere) to understand how they can be altered to enhance carbon sequestration in soils, such as by stimulating or reducing *in situ* specific metabolic process rates that regulate the quantities and chemical forms of reduced carbon sequestered in soils in long-term, stable pools. This research leverages BER’s more fundamental microbial systems biology research in Genomics: GTL and BER’s Carbon Sequestration Research in the Life Sciences area to evaluate the potential of molecular-based options for terrestrial carbon sequestration.

In FY 2006, a coupled model of physical, chemical, and biological processes in the ocean will be used to determine to what extent increased carbon fixation in surface waters would result in increased carbon sequestration in the deep ocean, how long carbon added to the ocean would remain in the ocean, and the changes in natural biogeochemical cycles that could result from carbon sequestration through iron fertilization of surface waters. This research leverages the ocean modeling capabilities developed in BER’s climate modeling program and completed field experiments. Surface Ocean carbon sequestration field experiments have been completed. Final results from the Southern Ocean Iron Experiment jointly funded with NSF will be published but no additional field research on ocean carbon sequestration will be supported by BER. Ocean carbon sequestration research will focus on the modeling activities discussed above.

Ecological Processes	**15,847**	**18,729**	**18,726**

In FY 2006, new ecological research will continue to develop a more mechanistic understanding of the scales of response of complex ecosystems to environmental changes, including identifying the underlying causal mechanisms and pathways and how they are linked, ranging from the proteomes of individual species to the whole ecosystem. The focus will be on understanding the linkages of scales in model terrestrial ecosystems containing simplified but hierarchical communities (higher plants, consumers of plant production, and soil microorganisms). A key environmental factor such as temperature that is known to affect ecosystem functioning (e.g., carbon and nutrient cycling) will be

	(dollars in thousands)	
FY 2004	FY 2005	FY 2006

experimentally manipulated and proteomic responses of individual species and the whole ecosystem will be measured. Advanced biologically based computational algorithms and ecosystem models will be developed to establish whether and how proteomic changes (in either single species or whole systems) explain the responses and behavior of complex ecosystems. Tools and principles developed from this research should have broad generality and eventual application to problems in carbon sequestration, ecological risk assessment, environmental restoration and cleanup, and early detection of ecological responses to climate change and other environmental factors.

BER will continue four Free-Air Carbon Dioxide Enrichment (FACE) experiments. They are located at facilities at Duke University (North Carolina), Rhinelander (Wisconsin), Oak Ridge (Tennessee), and Mercury (Nevada) on the Nevada Test Site. The experiments will improve understanding of the direct effects of experimentally elevated carbon dioxide and other atmospheric changes (such as elevated ozone) on the structure and functioning of various terrestrial ecosystems. Emphasis will be on understanding the cause of differential responses of plant species that may impact plant competition, succession, and productivity in terrestrial ecosystems. Research will explore changes, over time, in the effects of elevated atmospheric carbon dioxide concentrations on net primary productivity.

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

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

In FY 2006, a synthesis will be completed of known effects of increasing atmospheric carbon dioxide concentration, warming, and other factors (e.g., increasing tropospheric ozone concentration) on the structure and functioning of terrestrial ecosystems as determined by multi-factor experiments. This synthesis will fulfill one of the milestones of the U.S. Climate Change Science Program 2003 Strategic Plan.

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

Human Interactions	**8,073**	**8,149**	**8,071**

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

options, such as the capture of carbon dioxide and storage in geologic formations.

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

The Integrated Assessment research program will fund research to develop internally consistent sets of scenarios that can be used for national-scale decision-making. The scenarios will be evaluated in selected integrated assessment models, also funded by the Integrated Assessment program. In FY 2006, the Integrated Assessment research program will deliver an integrated assessment model that incorporates a global multi-country, multi-sector economics model and a 2-dimensional (2-D) model of the atmosphere (latitude and height) fully coupled with a 3-D ocean model and a 2-D (latitude and longitude) model of the terrestrial biosphere. To better address regional issues, this system will be extended to integrate fully coupled 3-D models of both the atmosphere and oceans. This much improved earth system model will allow, for the first time, an analysis of climate impacts at the regional level using an integrated model that includes both emissions data and climate responses. These analyses will facilitate, for example, regional studies of climate effects on human health and agriculture.

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

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

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

SBIR/STTR..	**0**	**3,917**	**3,894**

In FY 2004 $3,454,000 and $403,000 were transferred to the SBIR and STTR programs, respectively. For FY 2005 and FY 2006, amounts are the estimated requirements for continuation of these programs.

Total, Climate Change Research	**137,997**	**140,994**	**142,959**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Climate and Hydrology	
▪ The increased funding will accelerate development and application of 2- and 3-D cloud resolving models in atmospheric GCMs to explore the capabilities, data, and computational needs of the superparameterization approach to climate modeling.	+1,728
Atmospheric Chemistry and Carbon Cycle	
▪ Terrestrial carbon sequestration research maintained at near FY 2005 level.	+341
Ecological Processes	
▪ Ecological Processes research maintained at near FY 2005 level.	-3
Human Interaction	
▪ Integrated assessment research maintained at near FY 2005 level.	-78
SBIR/STTR	
▪ SBIR/STTR reduced due to research program reductions.	-23
Total Funding Change, Climate Change Research	**+1,965**

Environmental Remediation

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Environmental Remediation					
Environmental Remediation Sciences Research	59,929	58,111	48,600	-9,511	-16.4%
General Purpose Equipment (GPE)	959	959	403	-556	-58.0%
General Plant Projects (GPP)	4,811	5,584	6,140	+556	+10.0%
Facility Operations	39,059	37,228	37,138	-90	-0.2%
SBIR/STTR	0	2,574	2,413	-161	-6.3%
Total, Environmental Remediation	104,758	104,456	94,694	-9,762	-9.3%

Description

The mission of the Environmental Remediation subprogram is to deliver the scientific knowledge, technology, and enabling discoveries in biological and environmental research needed to underpin the Department of Energy's mission for environmental quality.

Benefits

The fundamental research supported in this subprogram will reduce the costs, risks, and schedules associated with the cleanup of the DOE nuclear weapons complex; extend the frontiers of methods for remediation; discover the fundamental mechanisms of contaminant transport in the environment; develop cutting edge molecular tools for investigating environmental processes; and develop an understanding of the ecological impacts of remediation activities. In addition much of the work performed for the cleanup program will provide fundamental knowledge that applies to a broad range of remediation problems, as well as to the development of advanced nuclear waste management approaches, and the prediction and avoidance of environmental hazards for future nuclear energy options.

Supporting Information

Research priorities include bioremediation, contaminant fate and transport, nuclear waste chemistry and advanced treatment options, and the operation of the William R. Wiley Environmental Molecular Sciences Laboratory (EMSL). The EMSL is supported as a national user facility providing advanced molecular tools to the scientific community in areas such as environmental remediation sciences, biology and genomics, atmospheric science and physical chemistry. In FY 2006, unique EMSL facilities, such as the newly upgraded Molecular Science Computing Facility, 900 MHz nuclear magnetic resonance (NMR) spectrometers, and the High-Field Mass Spectrometry Facility will expand both their scientific scope and their user base.

The Environmental Remediation Sciences subprogram was reviewed by a BERAC Committee of Visitors (COV) in 2004. The COV has issued its final report. The COV report was supportive of the subprogram and the approach to selecting and funding research projects. The major recommendation of the COV was that the Environmental Remediation subprogram integrate all research activities. The COV found Environmental Remediation activities well focused on the key science needs for DOE clean-up, e.g., the role of living organisms in the mobility of DOE-specific contaminants and high-level waste issues. While the Environmental Remediation subprogram was found to be well managed, the COV noted the need for improved documentation of funding decisions. BER has acted on the findings and recommendations by implementing a policy to consistently document the bases of funding decisions, expanding the documentation and providing summaries of the outcome of solicitations and to make these available to future COVs. The full report and the BER response is available on the BER web site (http://www.science.doe.gov/ober/berac.html).

At the recommendation of the BERAC COV, the Environmental Remediation subprogram has been reorganized. This new organization integrates research previously conducted under the Natural and Accelerated Bioremediation Research (NABIR) program, Environmental Management Science Program (EMSP), and the Savannah River Ecology Laboratory (SREL). Furthermore, the SREL will compete for funding within the Environmental Remediation subprogram rather than be included as a separately funded research activity. The integrated approach will provide complementary knowledge and capabilities that will optimize the research results over the structure that was established when three separate research activities from the Office of Science (BER) and the Office of Environmental Management were combined to form the subprogram in FY 2003.

The Environmental Remediation subprogram will develop fundamental understanding of biological, chemical and physical phenomena from molecular to field scales, that will enable resolution of DOE problems in environmental clean-up and stewardship, including: contaminant fate and transport; *in situ* remediation; radioactive waste treatment; characterization and performance monitoring. This will be accomplished by soliciting and funding a range of projects from lab-based, single investigator research to integrated multi-disciplinary activities to larger, field-based programs. This broad-based, tiered approach responds to the recommendations of the BERAC Environmental Remediation subcommittee and the COV. This restructuring removes artificial boundaries between programs that were legacies of having been developed in different DOE offices. This integration will enable the program to better address the BER long-term environmental remediation measure. Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes.

FY 2004 Accomplishments

Native Microbes Immobilize Waste Plume Contaminant. Field applications of laboratory-derived scientific advances are critical to real world evaluation of their potential value. Scientists from Pacific Northwest National Laboratory in collaboration with Stanford University have characterized the chemical nature of a mixed waste plume (including chromium and radionuclides) contaminating large volumes of soil beneath the Hanford waste tanks. These NABIR-funded researchers found that naturally occurring microbes in Hanford soils had immobilized nearly 50% of the chromium in the contaminated plume. These findings will help in the development of management strategies for the remaining contamination.

Microbes Remove Uranium from Contaminated Groundwater. The potential for removing uranium from contaminated groundwater by stimulating the activity of naturally microorganisms was evaluated in a uranium-contaminated aquifer located at an UMTRA (Uranium Mill Tailings Remedial Action) site in Rifle, Colorado. Acetate (a microbial energy source) was injected into the subsurface over a 3-month period. Uranium concentrations decreased in as little as 9 days after acetate injection was begun, and within 50 days uranium had declined below the prescribed treatment level in some of the monitoring wells. Analysis demonstrated that the initial loss of uranium from the groundwater was associated with an enrichment of a particular bacterial population (*Geobacter*) in the treatment zone. Subsequent monitoring showed a shift in the microbial community, associated with a decrease in the uranium immobilization effect. These results demonstrate that *in situ* bioremediation of uranium-contaminated groundwater is feasible and raise research questions into mechanisms to better maintain the long-term uranium removal activity of the resident *Geobacter* species.

Teaming to Solve Large Scientific Problems at the Environmental Molecular Sciences Laboratory. The EMSL has formed Collaborative Access Teams (CATs) consisting of scientists from PNNL, industry, universities, and other laboratories who work together using EMSL's facilities and equipment to rigorously focus on one area of high-impact research, such as oxide chemistry or structural biology. Results of this focused team concept will help solve larger scientific problems, bring new science capability to EMSL, and provide opportunities for expanding EMSL's user base. The first two CATs include: a Catalysis CAT (an integrated experimental and theoretical approach to a molecular-level understanding of oxide-catalyzed chemical transformations) and an Atmospheric Chemistry CAT (formed to lead the EMSL research thrust to address "atmospheric chemistry for the future").

Linking Biological Impacts with Specific Environmental Contamination. Chromatographic/spectrometric methods were used to demonstrate that selenium was present as selenomethionine in proteins extracted from tadpoles isolated from the Savannah River Site. The results support the hypothesis that selenium might be a cause of recorded abnormalities in these amphibians. SREL scientists hypothesize that selenomethionine (a non-essential selenium amino acid) might substitute for methionine in protein synthesis.

Light Sources Reveal Signatures of Contaminants in Trees. X-ray spectroscopy, using a beam line at the National Synchrotron Light Source at Brookhaven National Laboratory, is being used to determine metal speciation and contaminant distributions in soils, sediments, plants, and animals. Synchrotron x-ray fluorescence mapping of tree rings from a Savannah River Site with high soil concentrations of contaminants shows that trees collected from contaminated areas contain a "signature" of the metals within their annual rings. However, the study also revealed an important caveat. A tree growing in the middle of a contaminated settling pond with very high levels of nickel showed a dramatic peak in metal concentration in only one year suggesting that the tree had been able to avoid taking up excess nickel for most of its life. The sudden increase in nickel uptake observed in this study suggests that a branch of the tree's root system may have grown into a grossly contaminated "hot spot," taking up a potentially toxic level of nickel; one which would have almost certainly killed the root system in which it was in contact.

World's Largest Nuclear Magnetic Resonance (NMR) Spectrometer. The world's largest, highest-performance nuclear magnetic resonance (NMR) spectrometer is now operational at the EMSL. The 900-MHz NMR spectrometer fulfills a key part of the vision for EMSL by allowing scientists to conduct projects of large size or complexity that require the additional resolution and sensitivity a 900 MHz field can provide. The spectrometer will also be able to detect rare nuclei and to obtain orientation data from protein structures relative to solid surfaces. Probes for the NMR are being fine-tuned and the instrument is being "road-tested" prior to general use. The testing process has included evaluation of peptide lipid complexes and protein complexes ranging in size from 25 to 65 kilodaltons. Proposals for general use of EMSL's 900-MHz NMR spectrometer will be accepted in FY 2005.

EMSP Investigators Take Advantage of ORNL Clean Up Site Closure Activities. EMSP investigators adapted their research project to take advantage of ORNL's remediation scheme to cap buried waste. The scientists negotiated with the site to keep 14 multi-level wells and injection ports, extending them through the capping surface. Because the site had an extensive, long-term data set for fate and transport of material, these wells will allow study of the effects on the changes in hydrology, geochemistry, and microbial communities that occur with site capping. With capping likely to be a remediation method considered more frequently, such a study is both timely and unique.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Environmental Remediation Sciences Research..	**59,929**	**58,111**	**48,600**

The Environmental Remediation Sciences Research activity will address critical questions of fundamental environmental remediation science at the interfaces of biology, chemistry, geology and physics. Research results will provide the scientific foundation for the solution of key challenges and uncertainties at scales ranging from molecular to field, including the fate and transport of contaminants in the environment; strategies and opportunities for *in situ* remediation; strategies for the treatment of radioactive waste; and long-term characterization and monitoring of the performance of various remediation strategies.

The activity will support a tiered set of research projects that range from relatively small, specialized, single investigator, laboratory-based research projects to complex, multidisciplinary, large-scale research projects that translate and evaluate the results of laboratory research to real-world, i.e., field, conditions. The overall focus and integration strategy will center on field research since the ultimate goal of the Environmental Remediation Sciences activity is the development of science-based remediation strategies that can be implemented to solve real-world environmental problems. In addition to research on the scientific processes that control contaminant transport, this activity will develop new tools for measuring and characterizing the broad range of biological, environmental, and geophysical parameters associated with the behavior of contaminants in the environment. This broad-based, tiered approach responds to recommendations of the BERAC Environmental Remediation subcommittee and the Committee of Visitors.

This integrated research effort will lead to the development of improved models to predict, based on real-life observations, the transport of contaminants in the environment. Knowledge of the factors controlling contaminant mobility in the environment is essential to understand their long term behavior, before, during, and after remediation, and is a necessary step to achieve the long-term BER Program Goal. In FY 2006, the program will initiate new field-based research that complements ongoing work at the Oak Ridge Field Research Center (FRC). This new field-based research will allow scientists to bring concepts and hypotheses that can only be addressed at field scale, for example the coupled biological, chemical and hydrologic processes of subsurface contaminant behavior across multiple scales, to the field environment for real-world evaluation. The field research will focus on conditions and environmental problems extant at DOE sites that differ from those at the FRC site and will have broad applicability to existing research programs on heavy metals and radionuclides. It also will emphasize the interplay between experiment and model development as a critical component of both experimental design and model development and validation. The expanded field research activities will be used to evaluate and validate the results of laboratory-based science and predictive modeling efforts.

	FY 2004	FY 2005	FY 2006
	(dollars in thousands)		

This new, integrated research activity will more efficiently foster interdisciplinary research and be more responsive to new knowledge and to advanced computational and analytical tools that emerge from research at the EMSL and synchrotron light sources, from the GTL program, and to the needs of the DOE clean-up mission.

In FY 2006, BER will increase its focus on Genomics: GTL and Climate Change research in support of the DOE goals and objectives. The Environmental Remediation research subprogram will focus research efforts on subsurface science and high level radioactive waste in support of high priority DOE goals and objectives for environmental cleanup. As a result, research funding for surficial science including radioecology and surficial fate and transport will be phased out in FY 2005 and terminated in FY 2006.

	FY 2004	FY 2005	FY 2006
General Purpose Equipment (GPE).....................	**959**	**959**	**403**

GPE funding will continue to provide general purpose equipment for PNNL and ORISE such as information system computers and networks, and instrumentation that supports multi-purpose research.

	FY 2004	FY 2005	FY 2006
General Plant Projects (GPP)...............................	**4,811**	**5,584**	**6,140**

GPP funding is continued for minor new construction, other capital alterations and additions, and for buildings and utility systems, such as replacing piping in 30- to 40-year old buildings, modifying and replacing roofs, and HVAC upgrades and replacements. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and meeting the requirements for safe and reliable facilities operation. This activity includes stewardship GPP funding for Pacific Northwest National Laboratory (PNNL) and for Oak Ridge Institute for Science and Education (ORISE). The total estimated cost of each GPP project will not exceed $5,000,000.

	FY 2004	FY 2005	FY 2006
Facility Operations..	**39,059**	**37,228**	**37,138**
▪ **Operating Expenses**...	**33,790**	**32,039**	**35,149**

The EMSL is a scientific user facility located at the Pacific Northwest National Laboratory focused on conducting interdisciplinary, collaborative research in molecular-level environmental science. Operating funds are used for maintenance of buildings and instruments; utilities; staff support for users; environment, safety and health compliance activities; and communications. With over 55 leading-edge instruments and a supercomputer system, the EMSL annually supports approximately 1,600 users. University scientists form the core of the EMSL science team that networks with the broader academic community as well as with scientists at DOE National Laboratories and at other agencies. EMSL users have access to unique instrumentation for environmental research, including a new Linux-based supercomputer, a 900 MHz NMR spectrometer that adds to the suite of NMRs in EMSL, a suite of mass spectrometers, including an 11.5 Tesla high performance mass spectrometer, laser desorption and ablation instrumentation, ultra-high vacuum scanning tunneling and atomic force microscopes, and controlled atmosphere environmental chambers.

		(dollars in thousands)	
	FY 2004	FY 2005	FY 2006

In FY 2006 EMSL operations funding is provided to accommodate an anticipated large increase in the number of EMSL users conducting high-throughput proteomics and NMR-based protein structure research as part of the new multi-institutional, targeted research efforts in membrane biology and biogeochemistry. The large volume of data to be generated will be accommodated by the increased data storage capabilities in EMSL.

▪ **General Plant Projects (GPP)**	**1,250**	**3,200**	**0**

The GPP (TEC $4,450,000) for EMSL's Molecular Science Computing Facility (MSCF) adds approximately 4,000 sq. ft of additional space. The additional MSCF space is needed to meet the demand for new data storage systems due to the volume of data being generated by EMSL's high-throughput mass spectrometer, nuclear magnetic resonance (NMR) and other systems.

▪ **Capital Equipment**..	**4,019**	**1,989**	**1,989**

Capital equipment support for the EMSL enables instrument modifications needed by collaborators and external users of the facility as well as the purchase of state-of-the-art instrumentation to keep EMSL capabilities at the leading edge of molecular-level scientific research.

SBIR/STTR...	**0**	**2,574**	**2,413**

In FY 2004 $2,457,000 and $296,000 were transferred to the SBIR and STTR programs, respectively. FY 2005 and FY 2006, amounts are the estimated requirements for continuation of these programs.

Total, Environmental Remediation	**104,758**	**104,456**	**94,694**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)

Environmental Remediation Sciences Research

Environmental Remediation Sciences reduced based on fiscal constraints in FY 2006. BER will focus research activities on GTL and Climate Change in support of the DOE goals and objectives. The Environmental Remediation research subprogram will focus research efforts on subsurface science and high level radioactive waste in support of high priority DOE goals and objectives for environmental cleanup. As a result, research funding for surficial science including radioecology and surficial fate and transport will be phased out in FY 2005 and terminated in FY 2006.	-9,511

General Purpose Equipment (GPE)

GPE is reduced to make funds available for necessary GPP	-556

	FY 2006 vs. FY 2005 ($000)
General Plant Projects (GPP)	
GPP is increased for minor new construction and other capital alterations and additions needed to maintain safe, reliable, and productive operations of PNNL facilities................	+556
Facility Operations	
▪ EMSL Operations increased to accommodate an anticipated large increase in the number of EMSL users conducting high-throughput proteomics and NMR-based protein structure research as part of the new multi-institutional, targeted research efforts in membrane biology and biogeochemistry. The large volume of data to be generated will be accommodated by the increased data storage capabilities at EMSL..............	+3,110
▪ EMSL GPP decreased with the completion of the Molecular Science Computing Facility GPP project..............	-3,200
Total, Facility Operations..............	-90
SBIR/STTR	
▪ SBIR/STTR decreases with reduction in research..............	-161
Total Funding Change, Environmental Remediation..............	**-9,762**

Medical Applications and Measurement Science

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Medical Applications and Measurement Science					
Medical Applications	174,893	114,320	13,608	-100,712	-88.1%
Measurement Science	6,080	5,952	0	-5,952	-100.0%
SBIR/STTR	0	3,434	392	-3,042	-88.6%
Total, Medical Applications and Measurement Science	180,973	123,706	14,000	-109,706	-88.7%

Description

The mission of the Medical Applications and Measurement Science subprogram is to deliver the scientific knowledge and discoveries that will lead to new diagnostic and therapeutic tools and technology for disease diagnosis and treatment, non-invasive medical imaging technology, and bioengineering solutions to medical challenges.

Benefits

The basic research supported by the subprogram leads to new diagnostic and therapeutic technologies and reagents for the medical community that impact medical imaging and cancer treatment. The research also leads to the development of new medical devices such as neural prostheses, e.g., an artificial retina, that improve quality of life for affected patients.

Supporting Information

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

Today the subprogram seeks to develop new imaging technologies and new applications of radiotracers in diagnosis and treatment driven by the latest concepts and developments in genomic sciences, structural and molecular biology, computational biology, and instrumentation. Research capitalizes on the National Laboratories' unique resources and expertise in biological, chemical, physical, and computational sciences for technological advances related to human health. The expertise of the National Laboratories in micro-fabrication, micro-electronics, material sciences, and computer modeling provides the capability to develop intelligent micro-machines (e.g., the artificial retina) that interface with the brain to overcome disabilities and novel biomedical sensors with a broad range of biomedical applications including neural prostheses, such as the artificial retina.

Coordination with NIH is provided through joint participation of NIH research staff and management on BERAC Subcommittees, and NIH technical staff participation on BER merit review panels to reduce the possibility of undesirable duplications in research funding. DOE and NIH also organize and sponsor workshops in common areas of interest, for example: a joint workshop on Optical and X-ray Imaging, and Nanomedicine. Members of the Medical Sciences Program staff are formal members of the National Cancer Advisory Board, the BioEngineering Consortium (BECON) of NIH Institutes, and are on critical committees of the recently established National Institute of Bioimaging and Bioengineering (NIBIB). Program staff also participate in interagency activities such as the Multi Agency Tissue Engineering Science (MATES) working group that includes representatives of seven agencies and the Office of Science Technology Policy.

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

Periodic retrospective analysis will be employed to evaluate the accumulation of knowledge and validate specific outcomes. This program was examined as part of a BERAC review of the entire BER program in FY 2001. The next scheduled comprehensive review of the Medical Applications and Measurement Science subprogram by a BERAC COV will be in FY 2006.

FY 2004 Accomplishments

New Radiotracer to Image Heart Repair. A new PET radiotracer, fluorine-18 labeled pencyclovir has been developed at Stanford University for imaging transplantation of cells into the damaged heart to significantly improve heart function. This technology will allow imaging techniques to more precisely monitor the success of therapeutic interventions to treat heart attacks.

First Images of Gene Messages in Animals. Images of whole animals that detect the expression of three cancer genes were obtained for the first time by investigators in the Imaging Gene Expression Project at Thomas Jefferson University and the University of Massachusetts Medical Center. This advanced imaging technology will lead to the detection of cancer in humans using cancer cell genetic profiling.

New Radiolabeled Probes for Imaging Gene Expression. A consortium from BNL, LBNL and Ames has developed three unique classes of radiolabeled and fluorescent mRNA-binding probes capable of imaging mRNA in living cells. These tracers hold promise for the eventual imaging of gene messages of normal health and disease *in vivo* using PET.

A New Targeted Radiotherapeutic for Brain Tumors. Astatine-211 labeled chimeric anti-tenascin monoclonal antibody, has been developed at Duke University. This radiopharmaceutical has shown great promise for the treatment of brain tumors, including glioblastoma multiforme, and also might be valuable for treating other tumors that over express tenascin such as lymphoma.

New Radiotracer for Imaging Neurotransmission Function. A new PET radiotracer, C-11 labeled methylreboxetine, has been developed at BNL for imaging the brain *norepinephrine transporter (NET*) system. The use of this highly specific radiotracer will allow a better understanding of the neurotransmitter interactions in attention deficit hyperactivity disorder (ADHD), substance abuse, depression, and Alzheimer’s disease.

Brain Imaging Method to Explore Human Desire for Food. Using PET with fluorine-18 labeled glucose (FDG) and a newly developed food stimulation paradigm, scientists at BNL have demonstrated that smelling and tasting food without actually eating it increases brain metabolism. The PET images pinpointed the metabolic activity in the brain region that is involved in drug addiction. The research may help explain why people are so susceptible to even the suggestive effects of food in advertisements and may suggest new ways of dealing with the growing problem of obesity in this country.

LBNL Laser Wakefield Accelerator Technology. A new laser accelerator technology capable of accelerating electrons and subsequently protons to high energies (up to 100 MeV) in as little distance as a few millimeters for production of radioisotopes has been developed at LBNL. The technology represents a reduction in particle acceleration distance of nearly three orders of magnitude versus cyclotrons and linear accelerators. The technology has already been used to produce positron emitting isotopes, and holds promise for leading the development of table top accelerators for radioisotope production for medical diagnosis and treatment.

Magnetoencephalography (MEG) Technology for Acquiring Magnetic Resonance (MR) Images. MEG uses Superconducting Quantum Interference Device (SQUID) sensor technology for probing tiny magnetic fields in the brain generated from the currents that flow in the neuronal network. A team of scientists from LANL, using SQUID sensors, has for the first time measured the MEG signal from brain activity simultaneously with measurement of the magnetic resonance signal at ultra-low magnetic fields that can be used to generate MR images. This approach may prove important for people who cannot be subjected to the huge magnetic fields necessary to make a traditional MRI image.

Prototype for Mobile PET Scanner Developed. A PET scanner, small and light enough to sit on the top of the head of a rat, has been developed at Brookhaven National Laboratories through the BER advanced imaging technologies program. The scanner has advanced design microelectronics and small positron detectors. The goal of the program is to develop mobile PET scanners to detect psycho-neurological disorders in children.

New DOE Design for Artificial Retina. The development of a pliable, biocompatible 60 electrode artificial retina containing advanced microelectronics has undergone successful *in vitro* and acute safety testing in animals. Long term testing of the device in animals under long-term conditions that will be used in the eyes of blind patients are ongoing.

Progress in Helping the Blind to See. The institutions comprised by the DOE artificial retina program (ORNL; SNL; LANL; ANL; LLNL; DOE Vision Laboratory at the University of Southern California-Doheny Eye Institute; University of California, Santa Cruz; and North Carolina State) have signed a Cooperative Research and Development Agreement (CRADA) with the Second Sight Corporation of California. The CRADA will facilitate the translation of DOE supported advanced technology to devices that will satisfy FDA testing requirements for placement into blind patients.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Medical Applications	**174,893**	**114,320**	**13,608**
▪ **Medical Applications**	**39,011**	**36,941**	**13,608**

In FY 2006 BER supports basic research that builds on unique DOE capabilities in physics, chemistry, engineering, biology, and computational science. It supports fundamental imaging research, maintains core infrastructure for imaging research and development, and develops new technologies to improve the diagnosis and treatment of psycho-neurological diseases and cancer and the function of patients with neurological disabilities, such as blindness and paralysis. BER research develops new metabolic labels and imaging detectors for medical diagnosis; tailor-made radiopharmaceutical agents for treatment of inoperable cancers; and the capabilities to more accurately determine the structure and behavior of cells and tissues, information needed to engineer more effective or specific drugs, biosensors, and medical implants.

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

BER support for Boron Neutron Capture Therapy dosimetry, support programs at INEEL, and the core programs at Cornell University and INEEL to determine boron concentrations in biologic specimens is terminated after FY 2005. Molecular nuclear medicine research, research and technology development activities in imaging gene expression, magnetoencephalography, biosensors, PET instrumentation for human clinical applications, MRI and neuroscience research, radiation dosimetry for therapeutic dose estimation, and targeted molecular radionuclide therapy are curtailed in FY 2005 and terminated in FY 2006.

	FY 2004	FY 2005	FY 2006
▪ **Congressional Direction**	**135,882**	**77,379**	**0**

Congressional direction was provided in FY 2004 for University of Alabama-Huntsville Climate Action Project; University of South Alabama Cancer Center; Judson College library, academic and service center; Functional genomics research by the University of Kentucky and the University of Alabama; St. Joseph Hospital in Arizona; University of Arizona Institute for Biomedical Science and Biotechnology; Derby Center for Science and Mathematics at Lyon College; Southern California Water Education Center; St. Joseph Hospital technology upgrade in California; University of Southern California Center for Excellence in Neurogenetics; Vanguard University Science Center; National Childhood Cancer Foundation; Tahoe Center for Environmental Sciences; Christiana Comprehensive Cancer Initiative; Clean Energy Research at the University of Delaware; Eckerd College Science Center; Jacksonville University Environmental Science Center; Earth University Foundation in Georgia; Georgia State University Science Research & Teaching Lab; Mercer University Critical Personnel Development Program; Material research for energy security in Idaho; Cancer Center at Edward Hospital; Illinois Museum of Science and Industry; Northwestern University Institute of Bioengineering and Nanoscience in Medicine; Rush-Presbyterian-St. Luke's Medical Center; St. Francis Medical Center Rapid Treatment Unit in Illinois; St. Francis Hospital Emergency Services Department; Genomics research at Indiana University; Notre Dame Multi-Discipline Engineering Center; Tri-State University Technology Center; University of Dubuque Environmental Science Center; University of Northern Iowa building design and engineering; Biomedical Engineering Laboratory at the Center for Biomedical Engineering in Louisiana; Mary Bird Perkins Cancer Center; Morgan State University Center for Environmental Toxicology; Experimental Medicine Program at the Dana Farber Cancer Institute; Nuclear Resonance Mass Spectrometer at the University of Massachusetts Medical School; University of Massachusetts at Boston Multidisciplinary Research Facility and Library; Green power technology development at Grand Valley State University; Michigan Research Institute life sciences research; Michigan Technology Center for Nanostructure and Light Weight Materials; Augsburg College; CHP project at Mississippi State University; University of Missouri Cancer Center; Advanced bioreactor technology development in Montana; Boulder City Hospital Emergency Room Expansion; Digitalization of the Cardiac Cath Lab at the University Medical Center of Southern Nevada; Mega Voltage Cargo Imaging Development Applications for the Nevada Test Site; Nevada Cancer Institute; Research

Foundation at the University of Nevada-Las Vegas to assess earthquake hazards and seismic risk in Southern Nevada; Research Foundation at the University of Nevada-Las Vegas to conduct safety and risk analyses, simulation and modeling, systems planning, and operations and management to support radioactive and hazardous materials transportation; Space Grant Consortium at the Desert Research Institute; University of Nevada-Reno to conduct nuclear waste repository research in the areas of materials evaluation, fundamental studies on degradation mechanisms, alternate materials and design, and computational and analytical modeling; University of Nevada-Reno to expand the earthquake engineering and simulation facility; Upgrade the Grover C. Dils Medical Center; Upgrade the Pahrump Medical Center; Hackensack medical building in New Jersey; Hackensack University Medical Center; Robert Wood Johnson University Hospital; Upgrade the Drew University Hall of Science in New Jersey; Mental Illness and Neuroscience Discovery Institute; University of New Mexico medical building; Bronx Community Center for Sustainable Energy; College of Mount St. Vincent Science Hall; Comparative Functional Genomics at New York University; Genomics Laboratory at SUNY-Oneonta; University of Buffalo Center of Excellence in Bioinformatics; Rensselaer Polytech Center for Quantitative Bioscience; Structural Biology Research Center at the Hauptman-Woodward Medical Research Institute; Syracuse University Environmental Systems Center; Carolinas Medical Center; Western Carolinas Biotechnology Initiative; Community Improvement Corporation of Springfield-Clark County for a computing and data management center; Middletown Regional Hospital in Ohio; Ohio State University for environmental research in cooperation with Earth University; Carnegie Mellon University Green Chemistry Project; Urban Education Research Center in Pennsylvania; Clafin University Science Center; Coastal Research Center at the Medical University of South Carolina; University of South Carolina study of groundwater contamination; Life Sciences Facility, Tennessee State University; T3 MRI for St. Jude’s Children Research Hospital in Tennessee; University of Tennessee Climate Change Research Initiative; Center for Advanced Research in Texas; San Antonio Cancer Therapy and Research Center; Surgical robotics research at the Keck Cancer Center with the Cleveland Clinic; Huntsman Cancer Institute; Swedish American Regional Cancer Center; Adventist Health Care; Environmental Control and Life Support Project; UCLA - New Molecular Imaging Probes; Cedars Sinai Gene Therapy Research; Hartford Hospital Interventional Electro-Physiology Project; De Paul University – Biological Sciences; Coralville-Iowa Project on Alternative Renewable Energy Resources; and Western Michigan University – Nanotechnology Research and Computation Center.

Congressional direction was provided in FY 2005 for a science building at Waubonsee Community College in Illinois; digital playback hardware and software for Recording for the blind and dyslexic; All Children’s Hospital in Florida; Eckerd College in Florida; Applied Research and Technology Park electrical and communication infrastructure improvements in Springfield, Ohio; a Multiple Sclerosis, Alzheimer’s, Parkinson’s, Lou Gehrig’s Imaging System at the Cleveland Clinic in Ohio; Duchenne Muscular Dystrophy research-related equipment at Children’s National Medical Center in the District of Columbia; Duchenne Muscular Dystrophy research-related equipment at the University of Washington-Seattle; the Northeast Regional Cancer Center in Scranton, Pennsylvania; Ohio State University for environmental research in cooperation with Earth University; the University of Akron, Ohio, Polymer Center; the Ohio Northern University, Ada, Ohio, Science and Pharmacy Building; the Alabama A&M University; University of Texas at Arlington optical medical imaging equipment; the Missouri Alternative and Renewable Energy Technology Center, Crowder

College; the San Antonio, Texas, Cancer Research and Therapy Center; the University of South Alabama Cancer Center; the Virginia Commonwealth University Massey Cancer Center; the Saint Francis Hospital, Delaware, Cardiac Catheterization Lab; the Jacksonville University Environmental Science Center; the Houston, Texas, Alliance for Nanohealth; the Virginia Science Museum; the Polly Ryon Memorial Hospital, Texas; the St. Thomas University Minority Science Center, Miami, Florida; Project Intellicare, Roseville, California; the Virginia Polytechnic Institute Center for High-Performance Learning Environment; Georgia State University; the Michigan Research Institute for life science research; the University of Arizona Environment and Natural Resources Phase I1 Facility; the Children’s Hospital of Illinois ambulatory care project; the Loma Linda University, California, Medical Center synchrotron expansion; the University of Dubuque, Iowa, Environmental Science Center; the Ball State University, Indiana, Bioenergetics Research Initiative; the Clearfield Area School District, Pennsylvania, Energy Initiative; Digital Cardiology equipment at Children’s Hospital and Research Center, Oakland, California; the National Childhood Cancer Foundation; the Roswell Park Cancer Institute, New York, Center for Genetics and Pharmacology; Bucknell University, Pennsylvania, Materials Science Laboratory; the Science Center at Mystic Seaport, Connecticut; the Saratoga Hospital, New York, radiation therapy center; the San Joaquin Community Hospital, Bakersfield, California; the Syracuse University, New York, Environmental Systems Center; the University of Tennessee Sim Center; the St. Mary’s Hospital, Kankakee, Illinois; the Derby Center for Science and Mathematics at Lyon College in Arkansas; the Rush Presbyterian St. Lukes Medical Center in Illinois; Medical Research and Robotics at the University of Southern California; the Advanced Building Efficiency Testbed at Carnegie Mellon University; DePaul University Biological Sciences; the Philadelphia Educational Advancement Alliance; Northwestern University Institute of Bioengineering and Nanoscience in Medicine; the Rensselaer Polytechnical Institute Center for Bioscience; St. Peter’s Biotechnical Research in New Jersey; the Berkshire Environmental Center in Massachusetts; the Center for the Environment at the University of Massachusetts; technical upgrades at St. Joseph Hospital in Arizona; the Center for Science at the University of San Francisco in California; Augsburg College in Minnesota; the Bronx Community Center for Sustainable Energy; Marquette General Hospital in Marquette, Michigan; the Illinois-Indiana Super-Grid Program connecting Argonne National Laboratory and Purdue and Notre Dame Universities; the Purdue Calumet Water Environmental Institute; the Multi-Discipline Engineering Institute at Notre Dame in Indiana; the Energy Efficiency Project at Valparaiso University in Indiana; the Mental Illness and Neuroscience Discovery Institute in New Mexico; Military Spirit in New Mexico; the Academic Center Sustainable Design Project at St. Francis College, New York; the University of Louisville Pediatric Clinical Proteomic Center; the University of Louisville Institute for Advanced Materials; the Advanced Bioreactor located in Butte, Montana; to expand the Center for Integrated and Applied Environmental Toxicology at the University of Southern Maine; the University of Tennessee Cancer Institute; St. Jude Children’s Research Hospital in Tennessee; the Huntsman Cancer Institute; the Mega-Voltage Cargo Imaging Development Applications for the Nevada Test Site; the California Hospital Medical Center PET /CT Fusion Imaging System; the Luci Curci Cancer Center Linear Accelerator; Project Intellicare in California; the University Medical Center in Las Vegas, Nevada; the Southern California Water Education Center; Live Cell Molecular Imaging System at the University of Connecticut; the St. Francis Hospital Wilmington, Delaware, MRI and Cardiac Catherization Laboratory; the University of Delaware for the Delaware Biology Institute; the University of Nevada-Las Vegas School of Public Health; the Latino Development and

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

Technology Center; the Swedish American Health Systems; DePaul University Chemistry Lab Renovation Project; the Edward Hospital Cancer Center; the Mary Bird Perkins Cancer Center; the Morgan State University Center for Environmental Toxicology; the Suburban Hospital in Montgomery County, Maryland; the University of Massachusetts at Boston Multidisciplinary Research Facility and Library; the Martha's Vineyard Hospital; the Nevada Cancer Institute; the Mercy Hospital Grayling, Michigan Rural Healthcare Advancement Initiative; the Health Sciences Complex at Creighton University; the Hackensack University Medical Center Women and Children's Pavilion; the Kennedy Health System Linear Accelerator; the University of Buffalo Center of Excellence in Bioinformatics; the Hospital for Special Surgery National Center for Musculoskeletal Research; the New University in New York City; the Radiochemistry research facility at the University of Nevada-Las Vegas; the Hauptman-Woodward Medical Research Institute; the Vermont Institute of Natural Science; and the Tahoe Center for Environmental Services.

Measurement Science	**6,080**	**5,952**	**0**

Measurement Science Research is integrated with Medical Applications in FY 2006.

SBIR/STTR..	**0**	**3,434**	**392**

In FY 2004 $4,672,000 and $568,000 were transferred to the SBIR and STTR programs, respectively. FY 2005 and FY 2006 amounts are the estimated requirements for continuation of these programs.

Total, Medical Applications and Measurement Science..	**180,973**	**123,706**	**14,000**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Medical Applications	
The Medical Applications and Measurement Science research activities are integrated into a single subelement. Research will focus on fundamental imaging research (including radiopharmaceuticals for imaging), core infrastructure for imaging research and development, new technologies to improve the diagnosis and treatment of psycho-neurological diseases and cancer, and the function of patients with neurological disabilities, such as blindness and paralysis. Molecular nuclear medicine research, research and technology development activities in imaging gene expression, magnetoencephalography, biosensors, PET instrumentation for human clinical applications, MRI and neuroscience research, radiation dosimetry for therapeutic dose estimation, and targeted molecular radionuclide therapy are curtailed in FY 2005 and terminated in FY 2006.	-23,333
Congressional Direction	
Completion of Congressionally-directed projects.	-77,379
Measurement Science	
Measurement Science Research is integrated with Medical Applications.	-5,952
SBIR/STTR	
SBIR/STTR decreases as research program decreases	-3,042
Total Funding Change, Medical Applications and Measurement Science	**-109,706**

Construction

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Construction					
Project Engineering Design, Genomics: GTL	0	9,920	0	-9,920	-100.0%

Description

A possible facility to support Genomics: GTL research under the Biological and Environmental Research (BER) program.

Benefits

The Genomics: GTL facility for the Production and Characterization of Proteins and Molecular Tags, would surmount a principal roadblock to whole-system analysis by implementing high-throughput production and characterization of microbial proteins. It also would generate protein-tagging reagents for identifying, tracking, quantifying, controlling, capturing, and imaging individual proteins and molecular machines in living systems.

Detailed Justification

(dollars in thousands)

	FY 2004	FY 2005	FY 2006
▪ **Project Engineering and Design**	**0**	**9,920**	**0**

Project Engineering and Design (PED) funding for the Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags was initiated in FY 2005. This will be a cost-effective, high-throughput facility for the production of proteins, along with molecular tags for their identification. The proteins will mostly be from microbes and will be produced directly from the DNA sequences of microbes previously determined by BER. These proteins and molecular tags are necessary for the high-throughput characterization of molecular machines in DOE-relevant microbes with applications to DOE energy and environmental needs.

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
▪ **Project Engineering and Design**	
Funding was provided for Project Engineering and Design for the Genomics: GTL Facility for the Production and Characterization of Proteins and Molecular Tags in FY 2005	-9,920
Total Funding Change, Construction	**-9,920**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	6,061	8,784	6,140	-2,644	-30.1%
Capital Equipment	33,221	15,436	18,105	+2,669	+17.3%
Total Capital Operating Expenses	39,282	24,220	24,245	+25	+0.1%

Construction Projects

	(dollars in thousands)					
	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Unappro-priated Balance
PED, 05-SC-004 Production and Characterization of Proteins and Molecular Tags	9,920	0	0	9,920	0	0

High Energy Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
High Energy Physics					
Proton Accelerator-Based Physics	382,634	417,092	-15,972[ab]	401,120	387,093
Electron Accelerator-Based Physics	144,965	150,890	-6,961[ab]	143,929	132,822
Non-Accelerator Physics	47,385	42,936	+3,998[ab]	46,934	38,589
Theoretical Physics	49,433	49,630	-635[ab]	48,995	49,103
Advanced Technology R&D	79,327	81,081	+13,640[ab]	94,721	106,326
Subtotal, High Energy Physics	703,744	741,629	-5,930	735,699	713,933
Construction	12,426	751	-6[a]	745	0
Total, High Energy Physics	716,170[c]	742,380	-5,936	736,444	713,933

Public Law Authorizations:

Public Law 95-91, "Department of Energy Organization Act"

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

Mission

The mission of the High Energy Physics (HEP) program is to explore and to discover the laws of nature as they apply to the basic constituents of matter and the forces between them. The core of the mission centers on investigations of elementary particles, their nature and their mutual interactions, thereby underpinning and advancing the Department of Energy (DOE) missions and objectives through the development of key cutting-edge technologies and trained manpower that provide unique support to these missions.

Benefits

HEP supports DOE's mission of world-class scientific research capacity by providing world-class, peer-reviewed scientific results in high energy physics and related fields, including particle astrophysics and

[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005, as follows: Proton Accelerator-Based Physics ($-3,270,000); Electron Accelerator-Based Physics ($-1,253,000); Non-Accelerator Physics ($-321,000); Theoretical Physics ($-394,000); Advanced Technology R&D ($-692,000); and Construction ($-6,000).

[b] Includes a reallocation of funding in accordance with H. Rpt. 108-792, accompanying P.L. 108-447, as follows: Proton Accelerator-Based Physics ($-12,702,000); Electron Accelerator-Based Physics ($-5,708,000); Non-Accelerator Physics ($+4,319,000); Theoretical Physics ($-241,000); and Advanced Technology R&D ($+14,332,000). The reduction in Proton Accelerator-Based Physics subprogram is predominantly the result of the recategorization of costs associated with Non-Accelerator Research, Linear Collider R&D and Detector Development into other subprograms since the time the FY 2005 Congressional Budget was prepared. The current allocation in the Electron Accelerator-Based Physics subprogram reflects the current suspension of operations at the B-factory, with some of these funds redirected into compelling R&D for the future of HEP, particularly in the Non-Accelerator Physics and Advanced Technology R&D subprograms.

[c] Includes reductions of $4,347,000 rescinded in accordance with P.L. 108-137, the Consolidated Appropriations Act, 2004, $15,590,000, which was transferred to the SBIR program, and $1,871,000, which was transferred to the STTR program.

cosmology. Research advances in any one of these fields often have a strong impact on research directions in another. These fields also have a substantial overlap in technological infrastructure, including particle accelerators and detectors, data acquisition and computing. Technology that was developed in response to the demands of high energy physics research has also become indispensable to other fields of science and has found wide applications in industry and medicine, often in ways that could not have been predicted when the technology was first developed. Examples include: medical imaging, radiation therapy for cancer using particle beams, ion implantation of layers in semiconductors, materials research with electron microscopy, and the World Wide Web.

Strategic and Program Goals

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

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

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

Program Goal 05.19.00.00: Explore the Fundamental Interactions of Energy, Matter, Time and Space - Understand the unification of fundamental particles and forces and the mysterious forms of unseen energy and matter that dominate the universe; search for possible new dimensions of space; and investigate the nature of time itself.

Contribution to Program Goal 05.19.00.00 (Explore the Fundamental Interactions of Energy, Matter, Time and Space)

The High Energy Physics (HEP) program contributes to this goal by advancing our understanding of the basic constituents of matter, deeper symmetries in physical laws of particles at high energies, dark energy and dark matter, and the possible existence of other dimensions. HEP uses particle accelerators and highly sensitive detectors to study fundamental interactions at the highest possible energies. Because particle physics relates to the origin and evolution of the universe itself, the HEP program also supports studies of cosmic particles and phenomena that do not involve accelerators, including experiments deep underground, on mountain tops, or in space. This research at the frontier of science may discover new particles, forces or undiscovered dimensions of space and time; explain how matter came to have mass; and reveal the underlying nature of the universe. At the same time, the HEP program can shed new light on other mysteries of the cosmos, uncovering the mysterious dark matter that holds galaxies together and the even more mysterious dark energy that is stretching space apart; explaining why there is any matter in the universe at all; and showing how the tiniest constituents of the universe may have a leading role in shaping its birth, growth, and ultimate fate. Our goals in FY 2006 address all of these challenges. The FY 2006 budget request also contributes to this program goal by placing high priority on the operations, upgrades and infrastructure for the two major HEP user facilities (Tevatron and Neutrinos at the Main Injector [NuMI]) at the Fermi National Accelerator Laboratory (Fermilab), and the major HEP user facility (the B-Factory) at the Stanford Linear Accelerator Center (SLAC), to produce maximum scientific data to address these fundamental questions.

The following indicators establish specific long-term (10 year) goals in scientific advancement that the HEP program is committed to. They do not necessarily represent the research goals of individual experiments in the field. The order of the indicators corresponds roughly to current research priorities, and is meant to be representative of the program, not comprehensive:

- Measure the properties and interactions of the heaviest known particle (the top quark) in order to understand its particular role in the Standard Model, our current theory of particles and interactions.
- Measure the matter-antimatter asymmetry in many particle decay modes with high precision.
- Discover or rule out the Standard Model Higgs particle, thought to be responsible for generating the mass of elementary particles.
- Determine the pattern of the neutrino masses and the details of their mixing parameters.
- Confirm the existence of new supersymmetric (SUSY) particles, or rule out the minimal SUSY Standard Model of new physics.
- Directly discover, or rule out, new particles that could explain the cosmological “dark matter.”

These indicators spell out some of the important scientific goals of the HEP program for the next decade and can only be evaluated over a period of several years. However, each of these long-term goals is supported by one or more of the annual performance targets in Facilities Operations or Construction/Major Items of Equipment listed in the following table. Achieving success in these annual targets will be an important component of making progress towards the long-term goals.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 05.19.00.00 (Explore the Fundamental Interactions of Energy, Matter, Time and Space)					
All HEP Facilities					
	Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. [Met Goal]	*Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. [Met Goal]*	*Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time. [Met Goal]*	*Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time.*	*Maintain and operate HEP facilities such that unscheduled downtime is on average less than 20% of the total scheduled operating time.*
Proton Accelerator-Based Physics/Facilities					
Complete first phase of upgrades to enable the Tevatron to run at much higher luminosity. Begin commissioning of phase-one accelerator upgrades. *[Met Goal]*	Deliver data as planned (80 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned (225 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned within 20% of the baseline estimate (240 pb-1) to CDF and D-Zero detectors at the Tevatron. *[Met Goal]*	Deliver data as planned within 20% of the baseline estimate (390 pb-1) to CDF and D-Zero detectors at the Tevatron.	Deliver data as planned within 20% of the baseline estimate (450 pb-1) to CDF and D-Zero detectors at the Tevatron.
					Deliver 1×10^{20} protons on target for the MINOS experiment at NuMI facility.
Electron Accelerator-Based Physics/Facilities					
Double the total data delivered to BaBar at the SLAC B-factory by delivering 25 fb-1 of total luminosity. *[Met Goal]*	Increase the total data delivered to BaBar at the SLAC B-factory by delivering 35 fb-1 of total luminosity. *[Met Goal]*	Increase the total data delivered to BaBar at the SLAC B-factory by delivering 45 fb-1 of total luminosity. *[Not Met]*	Deliver data as planned within 20% of baseline estimate (45 fb-1) to the BaBar detector at the SLAC B-factory. *[Met Goal]*	Deliver data as planned within 20% of baseline estimate (50 fb-1) to the BaBar detector at the SLAC B-factory.	Deliver data as planned within 20% of the baseline estimate (100 fb-1) to the BaBar detector at the SLAC B-factory.
Construction/Major Items of Equipment					
	Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. *[Met Goal]*	Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. *[Met Goal]*	Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates. *[Met Goal]*	Maintain cost and schedule milestones for upgrades and new major construction projects within 10% of baseline estimates.	Maintain cost and schedule milestones for major items of equipment and new construction projects within 10% of baseline estimates.

Means and Strategies

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

The HEP program supports fundamental, innovative, peer-reviewed research to create new knowledge in areas important to the HEP mission, i.e., in experimental and theoretical particle physics, particle astrophysics, cosmology, and technology R&D. HEP also plays a critical role in constructing and operating a wide array of scientific user facilities for the Nation's researchers. All research projects undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program, and under a similar process for the laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

External factors that affect the programs and performance include: (1) changing mission needs as described by the DOE and Office of Science (SC) mission statements and strategic plans; (2) evolving scientific opportunities that sometimes emerge in a way that revolutionizes disciplines; (3) results of external program reviews and international benchmarking activities of entire fields or sub fields, such as those performed by the National Academy of Sciences; (4) unanticipated failures, for example, in critical components of scientific user facilities 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 HEP program in fundamental science is closely coordinated with the activities of other federal agencies (e.g., the National Science Foundation [NSF] and 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 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 HEP program has incorporated feedback from OMB into the FY 2005 and FY 2006 Budget Requests and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the HEP program a relatively high score of 84% overall which corresponds to a rating of “Moderately Effective.” OMB found performance improvements at Fermilab and an ongoing prioritization process. The assessment found that HEP has developed a limited number of adequate performance measures which are continued for FY 2006. These measures have been incorporated into this budget request, HEP grant solicitations and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain these complex scientific measures, the Office of Science has developed a website (*http://www.sc.doe.gov/measures/*) that answers questions such as “What does this measure mean?” and “Why is it important?” Roadmaps, developed in consultation with the High Energy Physics Advisory Panel (HEPAP — see *Advisory and Consultative Activities* below) and also available on the website, will guide reviews, every three years by HEPAP, of progress toward achieving the long-term performance measures. The annual performance targets are tracked through the Department’s Joule system and reported in the Department’s Annual Performance Report. In response to PART findings, HEP established a Committee of Visitors (COV) to provide outside expert validation of the program’s merit based review processes for impact on quality, relevance, and performance. The COV report is available on the web (*http://www.science.doe.gov/hep/HEPAPCOVReportfinal.pdf)*. Within 30 days of receiving the report, HEP developed an action plan to respond to its findings and recommendations. This action plan is also available on the web at (*http://www.sc.doe.gov/hep/OfficeofHEPResponsetoCOVreport.shtm*). The Particle Physics Project Prioritization Panel (P5 -- see *Advisory and Consultative Activities*) also submitted its first report in September 2003, and a revised update in August 2004. These reports are available on the web (*http://www.science.doe.gov/hep/hepap_reports.shtm*). HEP plans for future facilities, based upon that input, are reflected in this Budget Request.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 5.19.00.00, Explore the Fundamental Interactions of Energy, Matter, Time and Space			
Proton Accelerator-Based Physics	382,634	401,120	387,093
Electron Accelerator-Based Physics	144,965	143,929	132,822
Non-Accelerator Physics	47,385	46,934	38,589
Theoretical Physics	49,433	48,995	49,103
Advanced Technology R&D	79,327	94,721	106,326
Construction	12,426	745	0
Total, General Goal 5, World-Class Scientific Research Capacity	716,170	736,444	713,933

Overview

What is the nature of the universe and what is it made of?

What are matter, energy, space and time?

We have been asking basic questions like these about the nature of our world throughout human history. Today, these questions are addressed scientifically though research in **high energy physics**, also known as **particle physics**. The DOE High Energy Physics program and its predecessors have supported research into these fundamental questions for more than five decades.

In the last 30 years, this research has lead to a profound and far-reaching understanding of the fundamental particles and the physical laws that govern matter, energy, space and time. This understanding is encapsulated in a “Standard Model” that physicists use to predict the behavior of particles and forces. It has been subjected to countless experimental tests; and, again and again, its predictions have held true. The series of research breakthroughs that combined to produce the Standard

Model has been recognized with over a dozen Nobel Prizes and is celebrated as one of the great scientific triumphs of the 20th century.

But now, startling new data have revealed that only 5% of the universe is made of normal, visible matter described by the Standard Model. The other 95% of the universe consists of matter and energy whose fundamental nature is a mystery. The Standard Model's orderly and elegant view of the universe must somehow be incorporated into a deeper theory that can explain the new phenomena. A revolution in particle physics is coming.

Questions

A worldwide program of particle physics research is underway to explore the new scientific landscape. The possible pathways ahead have been defined in many complementary ways; here we choose the questions as defined in a recent HEPAP subpanel report, "The Quantum Universe":

- **Are there undiscovered principles of nature: new symmetries, new physical laws?**

  The quantum ideas that so successfully describe familiar matter fail when applied to cosmic physics. The problem might be solved by the appearance of new forces and new particles signaling the discovery of new symmetries—undiscovered principles of nature's behavior.

- **How can we solve the mystery of dark energy?**

  The "dark energy" that permeates empty space and accelerates the expansion of the universe must have a quantum explanation in the same way that the quantum theory of light and the atom explained mysterious atomic spectra and opened up a whole new way of seeing the universe. Dark energy might be similar to the Higgs field, a quantum field representing "vacuum energy" that exists throughout space.

- **Are there extra dimensions of space?**

  Current theories that attempt to reconcile quantum ideas with gravity predict the possible real existence of undiscovered dimensions of space that might explain much of the apparent complexity of particle physics. The discovery of extra dimensions would be an epochal event in human history. It would change our understanding of the birth and evolution of the universe and could affect the force of gravity at short distances.

- **Do all the forces become one?**

  At the most fundamental level all forces and particles in the universe are thought to be related, and all the forces are thought to be manifestations of a single unified force, Einstein's great dream. Recent theoretical efforts have made progress toward this goal.

- **Why are there so many kinds of particles?**

  Why do three families of particles exist, and why do their masses differ so dramatically? Patterns and variations in the families of elementary particles suggest undiscovered underlying principles that tie together the quarks and leptons of the Standard Model.

- **What is dark matter? How can we make it in the laboratory?**

  Most of the matter in the universe is unknown dark matter; probably particles produced in the Big Bang that interact very rarely with normal matter. These particles may have a small enough mass to be produced and studied at accelerators, or detected "au natural" with ultra-sensitive detectors.

- **What are neutrinos telling us?**

  Of all the known particles, neutrinos are the most mysterious. They played an essential role in the evolution of the universe, and their apparent tiny nonzero masses may imply new physics and unification at very high energies.

- **How did the universe come to be?**

  According to current cosmological ideas, the universe may have begun with a disturbance of space-time, followed by a burst of inflationary expansion of space itself. It is called the "Big Bang". Understanding the evolution of the universe requires breakthroughs in our understanding of quantum physics and quantum gravity. Following inflation, the universe cooled, passing through a series of phase transitions and allowing the formation of stars, galaxies, and ultimately life.

- **What happened to the antimatter?**

  The universe now is made almost entirely of matter, with very little extant antimatter, although the Big Bang, it is thought, must have produced the same amounts of matter and antimatter. How did the asymmetry arise?

All these questions are addressed at some level by the existing and planned HEP program described in the rest of this budget. Theoretical research, technology development, and a wide variety of experimental approaches are working hand-in-hand to provide new opportunities for further discoveries about the fundamental nature of the universe.

How We Work

The HEP program coordinates and funds high energy physics research. In FY 2004, the DOE HEP program provided about 90% of the federal support for high energy physics research in the nation; the NSF provides most of the remaining support. The program is responsible for: planning and prioritizing all aspects of supported research; conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders; supporting core university and national laboratory programs; and maintaining a strong infrastructure to support high energy physics research.

Advisory and Consultative Activities

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

The *High Energy Physics Advisory Panel (HEPAP)* provides advice to the DOE and NSF on a continuing basis regarding the direction and management of the national high energy physics research program. HEPAP regularly meets to advise the agencies on their research programs, assess their scientific productivity, and evaluate the scientific case for new facilities. HEPAP (or a subpanel thereof) also undertakes special studies and planning exercises in response to specific charges from the funding agencies. Non-accelerator-based research proposals to DOE and NSF are reviewed by a HEPAP subpanel called the *Scientific Assessment Group for Experiments in Non-Accelerator Physics (SAGENAP)*. 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 such as SAGENAP. Priorities recommended by P5 and SAGENAP will have an important influence on long-range planning (see *Planning and Priority Setting*, below). The *Astronomy and Astrophysics Advisory Committee (AAAC)* now reports to the DOE, as well as the NSF and NASA, on a continuing basis on the direction and management of the national astronomy and astrophysics research programs. The AAAC operates similarly to HEPAP and the two advisory bodies may form joint task forces or subpanels as needed to address research issues at the intersection of high energy physics, astrophysics and astronomy, such as dark energy and dark matter.

The *National Academy of Sciences* was chartered by Congress to advise the federal government on scientific and technical matters. It fulfills this function principally through the National Research Council (NRC) which conducts decadal surveys of research directions in all fields of physics and astronomy, as commissioned by its Board on Physics and Astronomy. Most recently, it conducted a "science assessment and strategy for…research at the intersection of astronomy and physics," published in 2003 as *Connecting Quarks with the Cosmos*. A new study is being carried out for DOE and NSF by the NRC in 2005-2006, which will assess and prioritize opportunities in high energy physics and the tools needed to realize them in the next 15 years.

DOE was part of the National Science and Technology Council's (NSTC) Interagency Working Group on the Physics of the Universe. In 2004, the Working Group released a strategic plan for how the agencies will address the recommendations from the *Connecting Quarks with the Cosmos* report. Included in this plan are specific recommendations for DOE to work together with the NSF and NASA to develop investments in emerging areas including dark energy, dark matter, and neutrino physics.

Laboratory directors seek advice from *Program Advisory Committees (PACs)* to determine the scientific justifications and priorities and the allocation of an important scientific resource—available accelerator beam time. Committee members, most of them external to the laboratory, are appointed by the director. PACs review research proposals requesting beam time and technical resources, judging each proposal's scientific merit and technical feasibility, and recommending whether the proposal should be approved, conditionally approved, deferred, or rejected.

Review and Oversight

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

The program also conducts annual in-depth reviews of the high energy physics program at each laboratory, using a panel of external technical experts. These on-site reviews examine the 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 dedicated activities at laboratories may also undergo peer review process in addition to the laboratory annual reviews to assess in detail the quality and relevance of the specific proposal. In addition, the HEP program began in FY 2004 to conduct regular, dedicated reviews of operations at its major user facilities in order to maintain high standards of performance and reliability. The HEP program also participates in the annual SC Institutional Reviews for each of its laboratories.

Review and oversight of construction activities are done by integrated technical, cost, schedule, and management reviews using teams of experts versed in the areas of activity pertinent to the particular project. These reviews are chaired by SC federal employees from outside the HEP program who are expert in project management, and the review results are provided directly to the project's DOE Acquisition Executive.

As noted above in the PART section, the HEP program has also instituted a formal "committee of visitors" that will provide an independent review of its responses to proposals and its research management process, as well as an evaluation of the quality, performance and relevance of the research portfolio and an assessment of its breadth and balance. The first such review took place in the second quarter of 2004. The committee report praised the program strongly, but also pointed to several areas that could be improved.

Planning and Priority Setting

One of the most important functions of HEPAP is the development of long-range plans that express community-wide priorities for future research. The most recent such plan was submitted in January 2002 and presented a "roadmap" for the field, laying out the physics opportunities they envision for the next 20 years. As part of this roadmap, the panel recommended that the highest priority of the U.S. program be a high energy, high-luminosity electron-positron linear collider to be built as a fully international effort. HEPAP further recommended that a vigorous long-term R&D program aimed toward future high energy research facilities be carried out with high priority within the HEP program.

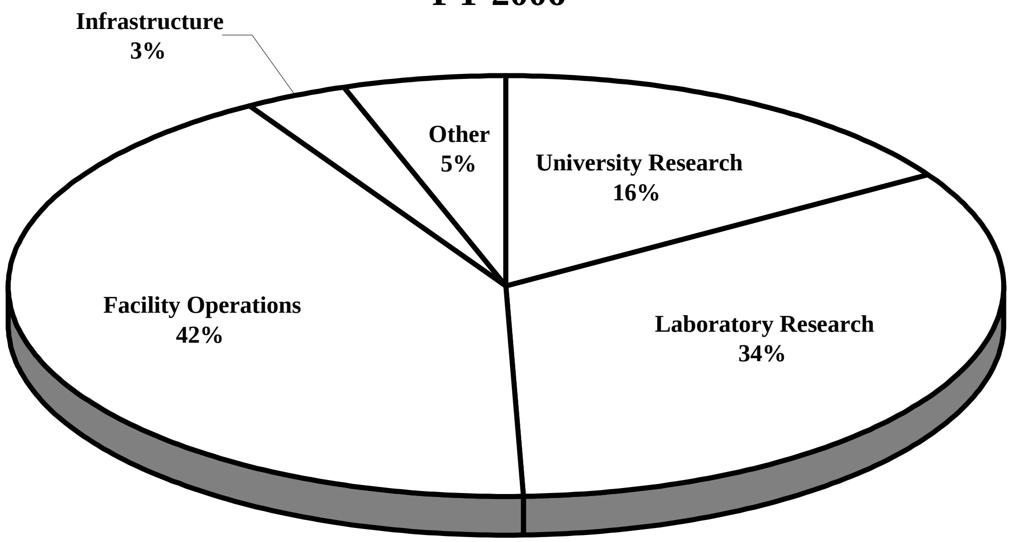
HEPAP also played an important role in advising the Director of the Office of Science on the future facilities needed to address all the centrally important HEP research questions for the next decade. Their recommendations on the scientific importance and technical readiness of several possible facilities were key elements in developing the Office of Science *Facilities Outlook*, published in 2003.

HEPAP also recommended a new mechanism to update the roadmap and set priorities across the program. This recommendation has been implemented in the form of the P5 that is charged with advising the funding agencies on priorities for new facilities with estimated costs in the range of $50-600 million. The first meeting of P5 was held in early 2003 and its first report on selected projects was delivered in late summer 2003. In 2004, P5 was charged to revisit some of its initial recommendations in the light of new data on project schedules. P5 will play an important role in determining which new facilities appear on the HEP roadmap in future years.

How We Spend Our Budget

The HEP budget has three major program elements: research, facility operations, and laboratory infrastructure support. About 42% of the FY 2006 budget request is provided to the two major HEP laboratories (Fermilab and SLAC) for facility operations; a total of 34% is provided to laboratories, including multipurpose laboratories, in support of their HEP research and advanced technology R&D activities; 16% is provided for university-based physics research and advanced technology R&D; 3% for infrastructure improvements (general plant projects [GPP] and general purpose equipment [GPE]); and 5% for other activities (including Small Business Innovative Research [SBIR] and Small Business Technology Transfer [STTR]). The FY 2006 budget request is focused on facility operations and upgrades at Fermilab and SLAC to advance research with the CDF and D-Zero detectors at the Tevatron, the Main Injector Neutrinos Oscillation Search (MINOS) detector using the NuMI beam and the BaBar detector at the B-factory. Also, a priority is given to the ramp-up of the Large Hadron Collider (LHC) research program in support of commissioning, operations and maintenance activities in anticipation of the start of the LHC physics program in 2007.

High Energy Physics Budget Allocation FY 2006



Research

The DOE HEP program supports approximately 2,450 researchers and students at over 100 U.S. universities located in 36 states, Washington, D.C., and Puerto Rico, and 10 laboratories located in 6 states. In addition, the HEP research program includes significant participation from university scientists supported by the NSF, a substantial number of scientists from foreign institutions, and astrophysicists supported by NASA. These physicists conceive and carry out the high energy physics research program. Typically, they work together in large international collaborations, involving hundreds of scientists from many institutions, to carry out a program that may take a decade or more to complete. Funding for accelerator-based university and laboratory research is down slightly compared to FY 2005 with a main emphasis on supporting research efforts focused on the large datasets now being generated by our user facilities. National laboratory research scientists work together with the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories provide state-of-the-art resources for detector and accelerator R&D needed for future upgrades and new facilities.

- ***University Research:*** University researchers play a critical role in the nation’s research effort and in the training of graduate students and postdoctoral researchers. During FY 2004, the DOE High Energy Physics program supported approximately two-thirds of the nation’s university researchers and graduate students engaged in fundamental high energy physics research. Typically, about 120 Ph.D. degrees are granted annually to students for research supported by the program.

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

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

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

Significant Program Shifts

The U.S. HEP program in FY 2006 will continue to lead the world with forefront user facilities producing data that help answer the key scientific questions outlined above, but these facilities will complete their scientific missions by the end of the decade. Thus we have structured the FY 2006 HEP program not only to maximize the scientific returns on our investment in these facilities, but also to invest in R&D now for the most promising new facilities that will come online in the next decade. This has required a prioritization of our current R&D efforts to select those which will provide the most compelling science within the available resources. In making these decisions we have seriously considered the recommendations of HEPAP and planning studies produced by the U.S. HEP community. This prioritization process will continue as the R&D programs evolve.

- Because of its broad relevance in addressing many of the long-term goals of the HEP program, and its unique potential for new discoveries, the highest priority is given to the planned operations, upgrades and infrastructure for the Tevatron program at Fermi National Accelerator Laboratory. This includes the completion of the upgrade to the Tevatron accelerator complex in 2007 to provide increased luminosity and additional computational resources to support analysis of the anticipated larger volume of data. Over the last few years, the laboratory has developed and implemented a detailed, resource-loaded plan for Tevatron operations and improvements, which has resulted in more reliable luminosity projections. The Office of Science has reviewed the plan and is actively engaged in tracking its progress.

- In order to fully exploit the unique opportunity to expand our understanding of the asymmetry of matter and antimatter in the universe, a high priority is given to the operations, upgrades and infrastructure for the B-factory at SLAC. Support for B-factory will include an allowance for increased power costs and fully funded upgrades for the accelerator and detector which are currently scheduled for completion in 2006. This includes: the completion of the upgrade to the accelerator complex and BaBar detector to provide more data; additional computational resources to support analysis of the larger volume of data; and, increased infrastructure spending to improve reliability. Funding for SLAC operations includes support from the Basic Energy Sciences (BES) program for the Linac Coherent Light Source (LCLS) project, marking the beginning of the transition of Linac operations from HEP to BES as B-factory operations are terminated by FY 2008 at the latest.

- As the LHC accelerator nears its turn-on date of 2007, U.S. activities related to fabrication of detector components will be completed and new activities related to commissioning and pre-operations of these detectors, along with software and computing activities needed to analyze the data, will ramp-up significantly. Support of a leadership role for U.S. research groups in the LHC physics program will continue to be a high priority for the HEP program.

- In order to explore the nature of dark energy, pre-conceptual R&D for potential interagency-sponsored experiments with NASA will continue in FY 2006. These experiments will provide important new information about the nature of dark energy and dark matter that will in turn lead to a better understanding of the birth, evolution and ultimate fate of the universe. At this time, no funding for a space-based DOE/NASA Joint Dark Energy Mission past the pre-conceptual stage has been identified.
- The engineering design of the BTeV ("B Physics at the Tevatron") experiment, which was scheduled to begin in FY 2005 as a new Major Item of Equipment, will be terminated by the end of FY 2005. This is also consistent with the guidance of HEPAP, which rated BTeV as of lesser scientific potential than other projects, although still important scientifically; and P5, which supported BTeV but only if it could be completed by 2010, which is not feasible given schedule and funding constraints.
- In FY 2009, at the end of Tevatron Run II, Fermilab will still be operating NuMI/MINOS for at least another year, and will participate in LHC and various particle astrophysics programs. The future of Fermilab past the end of the decade will be the subject of a continuing dialogue between the Administration, Congress, the laboratory, and the broader U.S. and international particle physics communities.
- In order to address the opportunity for significant new future research options, R&D in support of an international electron-positron linear collider is increased relative to FY 2005 to support the continued international participation and leadership in linear collider R&D and planning by U.S. scientists. The long-term goal of this effort is a construction start on an international Linear Collider in the next decade. To provide a nearer-term future program, and to preserve future research options, R&D for other new accelerator and detector technologies, particularly in the emerging area of neutrino physics, will also increase. The Linear Collider has been judged of the highest scientific importance by HEPAP as well as by advisory bodies of the Asian and European HEP communities.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all SC mission areas with the goal of achieving scientific breakthroughs via computer simulation that were unattainable using theoretical or laboratory studies alone. The power of computers and networks is increasing exponentially. Advances in high-end computing technology, together with innovative algorithms and software, are being exploited as intrinsic tools for scientific discovery. SciDAC has also pioneered an effective new model of multidisciplinary collaboration among discipline-specific scientists, computer scientists, computational scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can productively exploit terascale computing and networking resources. The program is bringing computation and simulation into parity with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate modeling and prediction, plasma physics, particle physics, accelerator design, astrophysics, chemically reacting flows, and computational nanoscience.

More details on the specific scientific impact of HEP contributions to SciDAC programs on lattice gauge Quantum ChromoDynamics (QCD) calculations, supernova simulations, accelerator simulation and modeling, and grid technology and deployment, as well as the FY 2006 work plan can be found below in the description of the Theoretical Physics subprogram.

Scientific Facilities Utilization

The High Energy Physics request supports the Department's scientific user facilities. This investment will provide significant research time for several thousand scientists based at universities and other Federal laboratories. It will also leverage both federally and privately sponsored research, consistent with the Administration's strategy for enhancing the U.S. national science investment.

The proposed funding will support operations at the Department's three major high energy physics facilities: the Tevatron and NuMI at Fermilab, and the B-factory at SLAC. The Tevatron provided a total of 3,960 hours of beam time in FY 2004 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. In FY 2005, construction of NuMI will be completed and operation of the facility will begin, serving over 300 researchers, of whom about two-thirds are U.S. researchers. The B-factory provided a total of 4,810 hours of beam time in FY 2004 for a research community of about 300 U.S. scientists in HEP and a comparable number of users from foreign countries. The FY 2006 Request will support facility operations that will provide ~4,560 hours of beams for each of the Tevatron and NuMI at Fermilab and ~5,200 hours of beams for B-factory at SLAC, including an allowance for increased power costs and fully funded upgrades.

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

	FY 2004	FY 2005	FY 2006
Tevatron Complex at Fermilab			
Optimal hours	4,320	4,320	4,800
Beam Hours - Tevatron	3,960	4,320	4,560
Unscheduled Downtime - Tevatron	<20%	<20%	<20%
Scheduled Hours - NuMI	N/A	N/A	4,560
Unscheduled Downtime - NuMI	N/A	N/A	<20%
Total Number of Users	2,160	2,160	2,125
B-factory at SLAC			
Optimal hours[a]	5,070	4,550	5,200
Beam hours[a]	4,810	3,380	5,200
Unscheduled Downtime	<20%	<20%	<20%
Total Number of Users	1,100	1,100	1,100

Construction and Infrastructure

Funding for construction and capital equipment is down significantly compared to FY 2005 as several projects are completed or ramping down. In addition, equipment funding at SLAC and Fermilab required to improve accelerator and detector complex reliability and performance is either completed or significantly ramping down. Funding for GPP is increased to renew site-wide infrastructure and to address deferred maintenance issues at Fermilab, SLAC, and Lawrence Berkeley National Laboratory (LBNL). Funding for Accelerator Improvement Projects (AIP) is down at Fermilab and SLAC relative

[a] B-factory operations have been suspended in FY 2005 pending the acceptance of a safety remediation plan. Optimal hours and beam hours shown are subject to change.

to FY 2005, as accelerator upgrade activities, designed to increase the rate of physics data delivered to experiments, begin to ramp down.

Workforce Development

The HEP program supports development of the R&D workforce through support of graduate students working toward a doctoral degree and post-doctoral associates developing their research and management skills. The R&D workforce developed under this program not only provides new scientific talent in areas of fundamental research, but also provides talent for a wide variety of technical, medical, and industrial areas that require the incisive thinking and problem solving abilities and computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as high energy physicists can be found working in such diverse areas as hospitals (radiation therapy, medical imaging, and medical physics), national security, space exploration, software and computing, telecommunications, finance, and many other fields.

About 1,200 postdoctoral associates and graduate students supported by the HEP program in FY 2004 were involved in a large variety of theoretical and experimental research, including advanced technology R&D. About one-fifth are involved in theoretical research. About 90% of those involved in experimental research utilize a number of scientific accelerator facilities supported by the DOE, NSF, and foreign countries; and about 10% participate in non-accelerator research.

Details of the High Energy Physics manpower are given below. These numbers include people employed by universities and laboratories. The university grants include Physics Research and Accelerator Technology grants. In FY 2004, there were 140 university grants with average funding of $850,000 per year. Most of these are multi-task grants with an average of three tasks. The duration of the grants is three years. The number of laboratory groups is an estimate of the number of distinct HEP research groups (experiment, theory, accelerator R&D) at the laboratories, which is a collection of single and multi-task efforts.

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	140	140	135
# Laboratory Groups	50	50	47
# Permanent Ph.D.'s (FTEs)	1,255	1,255	1,230
# Postdoctoral Associates (FTEs)	565	565	540
# Graduate Students (FTEs)	610	610	585
# Ph.D.'s awarded	120	120	115

In addition, there is a joint DOE/HEP and NSF research-based physics education program ("QuarkNet") aimed at professional development for high school teachers. In this program, active researchers in high energy physics serve as mentors for high school teachers to provide long term professional development based on participation in frontier high energy physics research. Through these activities, the teachers enhance their knowledge and understanding of science and technology research. They transfer this experience to their classrooms, engaging their students in both the substance and processes of contemporary research as appropriate for the high school classroom. For more details see the Detailed Justification section that follows.

Facilities Summary

Fermilab

In FY 2006, Fermilab plans 4,560 hours of running to achieve a performance goal of 450 inverse picobarns $(pb)^{-1}$ of data delivered to the major Tevatron experiments[a]. Approximately 900 people are involved in day-to-day Tevatron operations that include operation of the Tevatron accelerator complex and the CDF and D-Zero detectors. This is one of the major data collection periods for the experiments studying fundamental properties of matter and their interactions and also searching for supersymmetry, extra dimensions, and possible observation of the long-awaited Higgs boson at the world's energy frontier facility as described in more detail above.

Fully achieving the physics goals of the Tevatron program over the next few years has required a series of significant performance improvements to the accelerator. These efforts are proceeding in parallel with current Tevatron operations and research and are more fully described in the Detailed Justification sections that follow. The following table shows the funding profile to support the Tevatron Run II accelerator upgrades. The technical scope, cost and schedule of work for the Run II accelerator upgrades is periodically reviewed by the SC Construction Management Support Division and the reports from their reviews are available on the HEP website *http://www.science.doe.gov/hep/TevatronReports.shtm*. The most recent review of the Run II accelerator upgrade plan was conducted in September 2004, and the next review is scheduled for the second quarter of 2005.

Tevatron Run II Accelerator Luminosity Upgrades

(dollars in thousands)

FY 2004	FY 2005	FY 2006
33,140	18,440	8,800

Tevatron operations also include running the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This mode is used for physics data taking by the MINOS experiment and for test beam runs (both using 120 GeV protons extracted from Main Injector). During FY 2006, the MINOS experiment will be operating its beam line and detectors to collect data. Test beam runs will be scheduled as needed. These functions do not interfere with the high-priority Tevatron collider operations.

SLAC

In FY 2006, SLAC plans 5,200 hours of running to achieve a performance goal of 100 inverse femtobarns $(fb)^{-1}$ of data delivered to the BaBar experiment. Approximately 450 people are involved in day-to-day B-factory and BaBar operations. This will be the priority research program at SLAC in FY 2006. The collected data will provide a significant enhancement to the BaBar dataset for precision studies of Charge-Parity (CP) violation in the B-meson system, a phenomenon thought to be responsible for the excess of matter over antimatter in the universe. The opportunity to expand the boundaries of our

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[a] This unit measures the amount of accumulated data, expressed in particle interactions per unit cross-section. Cross-section is a measure of the probability of an interaction, and the unit of cross-section used in particle interactions is the barn, b, equal to 10^{-28} m^2. In interactions between high energy particles, smaller units such as the picobarn (pb = 10^{-12} b) or even femtobarn (fb = 10^{-15} b) are often used.

understanding of the origin of matter in the universe through the research conducted at this facility will continue to pay dividends in outstanding accelerator and detector performance and research quality and productivity. These efforts are more fully described in the Detailed Justification section in the Electron Accelerator-Based Physics subprogram.

HEP facilities operations funding is summarized in the table below for the Tevatron, NuMI and B-factory:

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Tevatron Complex Operations[a]	190,286	190,400	196,570
Tevatron Complex Improvements[b]	42,357	56,019	34,530
Total, Tevatron Complex	232,643	246,419	231,100
B-factory Operations	95,996	96,637	93,457
B-factory Improvements[c]	21,939	21,835	14,500
Total, B-factory	117,935	118,472	107,957

[a] Includes operations of Tevatron complex, NuMI beam line, and CDF, D-Zero, and MINOS detectors.
[b] Includes Run IIb CDF and D-Zero detectors and Tevatron Accelerator, R&D on possible future accelerator improvements, the MINOS detector, BTeV (in FY 2004 and FY 2005) and general improvements to the laboratory infrastructure. For details see the Detailed Justification section in the Proton Accelerator-Based Physics subprogram.
[c] Includes upgrades to the BaBar detector and B-factory accelerator, and general improvements to the laboratory infrastructure. For details see the Detailed Justification section in the Electron Accelerator-Based Physics subprogram.

Proton Accelerator-Based Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Proton Accelerator-Based Physics					
Research	76,359	75,656	75,424	-232	-0.3%
Facilities	306,275	325,464	311,669	-13,795	-4.2%
Total, Proton Accelerator-Based Physics	382,634	401,120	387,093	-14,027	-3.5%

Description

The mission of the Proton Accelerator-Based Physics subprogram is to foster fundamental research in high energy physics using proton accelerators that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Proton Accelerator-Based Physics subprogram exploits U.S. leadership at the energy frontier by conducting experimental research at high energy proton collider facilities. This experimental research program will determine whether the Standard Model correctly predicts the mechanism that generates mass for all fundamental particles and will search for the first evidence of new physics beyond the Standard Model.

The Proton Accelerator-Based Physics subprogram also includes accurate, controlled measurements of basic neutrino properties, including neutrino oscillations, at accelerator-based neutrino facilities. These measurements will provide important clues and constraints to the theory of matter and energy beyond the Standard Model. This subprogram addresses five of the six long-term indicators that contribute to the Program Goal as well as the majority of the key questions for HEP outlined in the Overview section above.

Supporting Information

The most immediate goal on the particle physics roadmap is to fully understand the unification of the electromagnetic and weak nuclear interactions into a single, "electroweak" force. This is expected to occur at an energy scale of about one trillion electron volts or 1 TeV. The Standard Model has successfully explained most particle physics phenomena below 1 TeV in energy, but beyond that energy range a new physical mechanism is needed to prevent Standard Model predictions from becoming inconsistent. Up until recently, it has been assumed that the Higgs boson is the solution to this "TeV scale" problem. Theories such as supersymmetry, extra hidden dimensions, and technicolor could solve the TeV scale problem in the Standard Model either in place of or in combination with, a Higgs boson. No matter which of these theories is shown to be correct, it will provide a deeper understanding of the fundamental nature of matter, energy, space and time. A single, "standard" Higgs boson would explain the origin of mass. Supersymmetry — which has multiple Higgs bosons — not only explains the origin of mass, but could also lead to the next step in unification: combining the electroweak interaction with the strong nuclear interaction. Discovery of hidden dimensions could point the way to a unification of gravity with the other forces of nature.

The major activities under the Proton Accelerator-Based Physics subprogram are broad research programs using the CDF and D-Zero detectors at the Tevatron at Fermilab; the neutrino research program using the NuMI/MINOS facility at Fermilab and at the Soudan Mine site in Minnesota; the LHC program; and maintenance and operation of these facilities. The Tevatron collider programs will address many key questions about the Standard Model and the physics of the “TeV scale” as described above. The NuMI/MINOS program will perform decisive controlled measurements of fundamental neutrino properties, including neutrino oscillations that will provide important clues and constraints to the theory of matter and energy beyond the Standard Model. The LHC program will substantially increase the power of the U.S. high energy physics research program to explore physics beyond the Standard Model and will enable it to be a key player at the next energy frontier. There are also much smaller specialized efforts at other accelerators worldwide.

Physics at the energy frontier is the primary thrust of the Proton Accelerator-Based Physics subprogram. In FY 2006, the energy frontier remains at the Fermilab Tevatron. The CDF and D-Zero experiments will make precision measurements of known particles, like the mass of the W boson and the top quark – by far the most massive fundamental particle known. The number of top quarks accumulated and studied during the previous Tevatron collider run was less than 100. The new run will produce an order of magnitude more top quarks and allow a serious study of its mass, spin, and couplings. These precision measurements give indirect but important information about the major theories on electroweak unification and that information can guide and constrain the direct searches. They will also pursue the questions of electroweak unification with direct searches for the Higgs Boson, supersymmetry, and hidden dimensions.When the LHC at the European Organization for Nuclear Research (CERN) is operational, the energy frontier will move there and the Compact Muon Solenoid (CMS) and A Toroidal LHC Apparatus (ATLAS) experiments will take over the program begun at the Tevatron.

The Tevatron at Fermilab is the highest-energy particle accelerator in the world. It produces collisions of 1 TeV protons with 1 TeV antiprotons. Because of the high energy of the collisions and the fact that the particles interact in several different ways, the collisions can be used to study a wide variety of physics topics. All of the six different types of quarks are produced in these interactions, and the heaviest, the top and bottom quarks, are of the greatest interest. Most of the force-carrying particles are also directly produced and if the masses of predicted – but as yet unobserved – particles, such as the Higgs boson or supersymmetric particles, are low enough, they will also be produced at the Tevatron. Its two large general-purpose detectors, CDF and D-Zero, mine this rich lode of physics. Precise measurements of the mass of the W boson and detailed studies of the charm quarks will also be carried out.

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

Today, neutrino physics presents one of the most promising avenues to probe for extensions of the Standard Model. *A priori*, there is no fundamental reason why neutrinos should not have mass or why there should be no mixing between different neutrino species. In the last decade, a number of interesting new results have been reported by several different experiments, including the Liquid Scintillation Neutrino Detector (LSND) experiment at Los Alamos, the Super-K and KamLAND experiments in Japan and the Sudbury Neutrino Observatory experiment in Canada. These experiments provide compelling evidence that neutrinos do have mass and that they do change their identities (the different neutrino species “mix”) as they travel. Unfortunately, the neutrinos used by these experiments have a wide range of energies and are produced in insufficient numbers to precisely measure their mixing parameters. One of the unique opportunities in the Proton Accelerator-Based Physics subprogram is to explore and make precision measurements of neutrinos generated at dedicated proton beam facilities in a well-controlled environment (e.g., the Neutrinos at the Main Injector beam at Fermilab).

Research and Facilities

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

The Facilities category in the Proton Accelerator-Based Physics subprogram supports maintenance, operation, and technical improvements for proton accelerator facilities in the U.S. In addition, this category supports the U.S. share of detector maintenance and operations, software and computing infrastructure, and directed technical R&D for international proton accelerator facilities such as the LHC at CERN. Facilities activities include: installation, commissioning, maintenance and operations of accelerators and experiments; provision of computing hardware and software infrastructure to support the experiments and the accelerators, and provision of platforms for data analysis; and directed R&D for accelerator and detector enhancements and performance improvements. Since physicists are often involved in these activities as well as research activities, some are partially supported by both categories of funding where appropriate.

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

Highlights

Most recent research highlights reflect milestones in completion, operations, or preparation for operations of new experiments and facilities. This subprogram is in transition to focus on operations and data analysis for maximum science in future years. Recent accomplishments include:

- The CDF and D-Zero detectors at Fermilab have collected over three times more data in Run II of the Tevatron collider than in all of Run I (1992-1996). The collaborations published their first papers from Run II in 2004 and have presented a large number of new results at conferences. These detectors have much greater sensitivity than before and will make numerous high-precision measurements, including the masses of the top quark and the W boson.
- A new accelerator-based neutrino program in the U.S. was launched in 2002 when the MiniBooNE detector at Fermilab began taking data using a low-energy proton beam to confirm or refute hints of neutrino oscillations discovered at Los Alamos in the LSND experiment. The initial phase of data taking will be completed and results are expected by summer of 2005.

- The MINOS far detector in the Soudan mine has been completed ahead of schedule and has operated with cosmic rays since the summer of 2003. The near detector at Fermilab has been installed and is being commissioned. The NuMI beamline begins commissioning in early 2005.
- The LHC Software and Computing program will continue in order to develop, design and implement a computing system to process, store and support the analysis of the huge amount of data anticipated after the LHC begins commissioning in FY 2007. A parallel effort began in 2002 to test, commission, and eventually operate the U.S.-supplied systems that are part of the LHC detectors. A significant ramp-up of these activities will continue in FY 2006 in anticipation of the LHC accelerator turn on in 2007.

The major planned efforts in FY 2006 are:

- *The research program using the Tevatron at Fermilab*. This research program is being carried out by a collaboration including 1400 scientists from Fermilab, ANL, BNL, LBNL, 56 U.S. universities, and institutions in over 20 foreign countries. The major effort in FY 2006 will be data taking with the fully upgraded CDF and D-Zero detectors. The physics issues to be addressed include searches for the Higgs boson, supersymmetry or other new phenomena; B meson studies including charge-parity (CP) violation; and precision measurements of the top quark and the W boson properties.
- *The research program using the NuMI/MINOS Facilities at Fermilab and the Soudan Mine*. This research program is being carried out by a collaboration including 250 scientists from Fermilab, ANL, BNL, Lawrence Livermore National Laboratory (LLNL), 16 U.S. universities, and institutions in 4 foreign countries. The major effort in FY 2006 will be data taking and analysis, along with optimizing accelerator performance to improve beam intensity for higher statistics.
- *Planning and preparation for the U.S. portion of the research program of the LHC*. A major effort in FY 2006 will continue to be the design and implementation of the U.S. data handling and computing capabilities needed for full participation in the LHC research program. Pre-operations of U.S.-supplied detectors for LHC experiments will continue at CERN.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research...	**76,359**	**75,656**	**75,424**
▪ **University Research**..	**46,453**	**44,470**	**44,470**

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

In FY 2006, the overall level of support is unchanged. Full participation of university physicists is needed to exploit the physics potential of the very active program at the Tevatron and the increase in installation and commissioning activities on the LHC experiments, CMS and ATLAS, during FY 2006. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in the targeted physics research activities. These include research efforts related to the high-priority experiments such as CDF and D-Zero, work to support the fabrication of the LHC detector components, and work on the preparation for U.S. participation in the LHC research program.

	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**28,659**	**29,885**	**29,554**

The national laboratory research program consists of groups at several laboratories participating in experiments at proton accelerator facilities. These groups participate in all phases of the experiments, with the focus of the physics program being similar to that of the university groups described above. Although they lack the specific educational mission of their colleagues at universities, they are imbedded in the laboratory structure and therefore provide invaluable service to the research program in detector design, construction, and operations. The DOE HEP program office reviews laboratory research groups annually with input from independent peer reviewers. Proton accelerator activities concentrate on experiments at the Tevatron complex at Fermilab and the Large Hadron Collider, under construction at CERN.

In FY 2006, the national laboratory research program is slightly reduced because of the need to support facility operations. Full participation of national laboratory physicists is needed to exploit the physics potential of the very active program at the Tevatron during FY 2006. The laboratory experimental physics research groups will be focused mainly on data taking with the CDF and D-Zero collider detector facilities, and analysis of data taken during previous years; operations of the MINOS detector using the neutrino beam from NuMI; support for the MiniBooNE experiment; support for pre-operations of the ATLAS and CMS detectors for the LHC; and for physicists working on preparation for U.S. participation in the LHC Research Program.

The Fermilab research program ($12,983,000) includes data taking and analysis of the CDF, D-Zero, and MiniBooNE experiments, the CMS research and computing program, and data taking and analysis of the MINOS detector. These activities by physicists at the host laboratory provide the necessary close linkages between the Research and the Facilities categories in the Proton Accelerator-Based Physics subprogram.

Research activities at LBNL ($5,165,000) will be dominated by the ATLAS research and computing program, along with analyzing data from the CDF and D-Zero experiments.

Activities by the BNL research group ($7,356,000) will cover data taking and analysis of the D-Zero experiment, the ATLAS research and computing program, preparation for future NSF-funded experiments, and a small effort on the MINOS experiment.

The research group at ANL ($4,050,000) 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.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **University Service Accounts**	**1,247**	**1,301**	**1,400**

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

Facilities	**306,275**	**325,464**	**311,669**

	FY 2004	FY 2005	FY 2006
Facilities			
Tevatron Complex Operations	190,286	190,400	196,570
Tevatron Complex Improvements	42,357	56,019	34,530
Large Hadron Collider Project	48,800	32,500	7,440
Large Hadron Collider Support	15,600	29,400	52,640
AGS Operations/Support	650	650	637
Other Facilities.	8,582	16,495	19,852
Total, Facilities	306,275	325,464	311,669

▪ **Tevatron Complex Operations**	**190,286**	**190,400**	**196,570**

Operations at Fermilab will include operation of the Tevatron accelerator complex in collider mode and operations of two collider detectors for about 4,560 hours. This will be a major physics run for the D-Zero and CDF detectors with the higher intensity available from the Main Injector.

This is to be one of the major data collection periods for the experiments pursuing physics topics from the energy frontier facility as described in more detail above.

The Tevatron has shown significant performance improvement through FY 2003 and FY 2004. The Run II improvement plan has been reviewed three times in FY 2003 and 2004 with improving evaluations at each review. The FY 2006 budget for Tevatron Complex Operations draws from the plans submitted to these reviews. Funding for associated luminosity improvements is discussed below under Tevatron Complex Improvements.

Tevatron operations also include the running of the Tevatron complex in fixed target mode in parallel with Tevatron collider operation. This running mode will be primarily for the physics data taking of MINOS experiment using the NuMI beamline.

	FY 2004	FY 2005	FY 2006
Tevatron Complex Operations in hours	3,960	4,320	4,560

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Tevatron Complex Improvements**	**42,357**	**56,019**	**34,530**

This funding includes specific improvements to the Tevatron collider complex to substantially increase the rate of data delivery support for improvement to the associated detectors to enable them to handle the higher data rates, and significant increases to accelerator maintenance and operational support to improve Tevatron reliability.

Funding in the amount of $7,800,000 is included in this budget category for the program to increase the Tevatron luminosity, and provide the computing capability needed to analyze the data collected. Plans for luminosity upgrades involve several steps toward increasing the number of antiprotons in the Tevatron, since that is the main factor that enables higher luminosity. In FY 2006, this effort will be concentrating on improvements to the Tevatron ring itself, so that the largest number of antiprotons generated by the FY 2005 improvements can be successfully stored in the Tevatron. Funding for Tevatron upgrades follows the planned profile of the luminosity upgrade. Since the detector upgrades have been completed and the accelerator upgrades are near completion, funding for this activity decreases by $16,080,000 from FY 2005.

Funding in the amount of $26,730,000 is included for Other Tevatron Improvement activities (other than those specified above). Funding for this category decreases in FY 2006 by $5,409,000 due to the cancellation of the engineering design for the BTeV project ($-10,250,000; noted above in Significant Program Shifts) and the completion of the MINOS project in FY 2005 ($-550,000), offset by increases to accelerator R&D and support activities related to increasing the proton flux on target for the NuMI beam ($+3,935,000), and support for the critical laboratory infrastructure, particularly the high voltage power system needed to run the accelerator ($+1,456,000).

▪ **Large Hadron Collider Project**......................	**48,800**	**32,500**	**7,440**

Changes were made in 2003 to better match the funding profile to the funding needs of: (1) the three U.S. LHC fabrication projects based on their current fabrication plans and schedules; and (2) the updated LHC construction schedule as determined by CERN. This funding profile will allow the project to continue on the revised approved CERN schedule and will not affect the planned completion date or the total cost of the U.S. projects and the LHC itself.

Construction and technical difficulties in the CERN funded portion of the LHC project on the CERN site in Geneva, Switzerland have led to delays in the project. The problems are being overcome and the latest CERN schedule has first collisions in 2007. While the U.S. does not control the LHC schedule, we maintain active contact with CERN management and the U.S. LHC project managers to ensure that schedules for U.S. deliverables conform to the latest official LHC schedules issued by CERN.

The detailed schedules of the three U.S. LHC projects have been reviewed in the context of this schedule revision by CERN. The U.S. LHC Accelerator Components Project is expected to be completed in FY 2005. The U.S. detector projects (ATLAS and CMS) will complete ~95% of their planned work by the previously scheduled end-date (fourth quarter FY 2005), but for each, a small amount of work is intimately tied to the late stages of the CERN schedule. This is primarily work directly related to the final assembly, testing, and installation of the full detectors, as well as purchase of computing hardware for data acquisition. Under the current schedule, this work will occur in 2006 and 2007, changing the final project completion date. The increased costs arising from the delay are modest and will be contained within the projects' contingency allowances. The result of these changes is a stretch out of the planned U.S. contributions to the LHC detectors by two years. The FY 2006 funding for the detectors reflects the stretch out plans. The final cost of each detector is unchanged.

Participation by the U.S. in the LHC program is extremely important to U.S. High Energy Physics program goals. The LHC will become the foremost high energy physics research facility in the world when it begins commissioning in 2007. The LHC will have a center-of-mass energy seven times that of the Tevatron at Fermilab, thus opening up substantial new frontiers for scientific discovery.

With the LHC at the next energy frontier, American scientific research at that frontier depends on participation in LHC. The HEPAP Subpanel on Vision for the Future of High Energy Physics strongly endorsed participation in the LHC, and this endorsement has been restated by HEPAP on several occasions.

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

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

Participation in the LHC project (accelerator and detectors) at CERN primarily takes the form of the U.S. accepting responsibility for designing and fabricating particular subsystems of the accelerator and of the two large detectors. Thus, much of the funding goes to U.S. laboratories, university groups, and industry for fabrication of subsystems and components that will become part of the LHC accelerator or detectors. A portion of the funds is being used to pay for purchases by CERN of material needed for construction of the accelerator from U.S. vendors.

The agreement provides for a U.S. DOE contribution of $450,000,000 to the LHC accelerator and detectors (with an additional $81,000,000 being provided by the NSF). The DOE contribution is broken down as follows: detectors $250,000,000 and accelerator $200,000,000 (including $90,000,000 for direct purchases by CERN from U.S. vendors and $110,000,000 for fabrication of components by U.S. laboratories).

The total cost of the LHC on a basis comparable to that used for U.S. projects is estimated at about $6,000,000,000. (The LHC cost estimates prepared by CERN, in general, do not include the cost of permanent laboratory staff and other laboratory resources used to construct the project.)

(dollars in thousands)		
FY 2004	FY 2005	FY 2006

Neither the proposed U.S. DOE $450,000,000 contribution nor the estimated total cost of $6,000,000,000 include support for the European and U.S. research physicists working on the LHC program.

The agreement negotiated with CERN provides for U.S. involvement in the management of the project through participation in key management committees (CERN Council, CERN Committee of Council, LHC Board, etc.). This provides an effective base from which to monitor the progress of the project, and will help ensure that U.S. scientists have full access to the physics opportunities available at the LHC. SC has conducted a cost and schedule review of the entire LHC project and similar reviews of the several proposed U.S. funded components of the LHC. All of these reviews concluded the costs are properly estimated and that the schedule is on track.

In addition to the proposed U.S. DOE $450,000,000 contribution and $81,000,000 NSF contribution to the LHC accelerator and detector hardware fabrication, U.S. participation in the LHC will involve a significant portion of the U.S. High Energy Physics community in the research program at the LHC. This physicist involvement has grown dramatically with over 700 U.S. scientists joining the U.S.-ATLAS detector collaboration, the U.S.-CMS detector collaboration, or the U.S.-LHC accelerator consortium. Most of the effort in FY 2006 will be devoted to the Research Program, which will deploy the infrastructure necessary for U.S. scientists to exploit the physics potential presented by the new energy frontier during first collisions in 2007.

U.S. LHC Accelerator and Detector Funding Profile

(dollars in thousands)

Fiscal Year	Department of Energy			National Science Foundation[a] (Detector)
	Accelerator	Detector	Total	
1996[b]	2,000	4,000	6,000	0
1997[b]	6,670	8,330	15,000	0
1998[b]	14,000	21,000	35,000	0
1999	23,491	41,509	65,000	22,150
2000	33,206	36,794	70,000	15,900
2001	27,243	31,627	58,870	16,370
2002	21,303	27,697	49,000	16,860
2003	21,310	37,900	59,210	9,720
2004	29,330	19,470	48,800	0
2005	21,447	11,053	32,500	0
2006[c]	0	7,440	7,440	0
2007	0	3,180	3,180	0
Total	200,000[d]	250,000	450,000	81,000

[a] The NSF funding was approved by the National Science Board.
[b] The FY 1996 and FY 1997 LHC funding was for R&D, design and engineering work in support of the proposed U.S. participation in LHC. Beginning in FY 1998 funding was used for: fabrication of machine and detector hardware, supporting R&D, prototype development, and purchases by CERN from U.S. vendors.
[c] At the end of FY 2005 approximately 95% of the U.S. CMS and U.S. ATLAS projects will be completed on schedule. The remaining 5% of the project scope is integrally connected to the CERN portion of the project. As such, the recent slip in the CERN project schedule will significantly impact our ability to complete the remaining 5% of this project on the present schedule. The 95% portion of this project that will be complete at the end of FY 2005 will be closed out at that time. The remaining 5% of the project will continue, consistent with DOE project management policies and practices. Based on CERN's current schedule, it is anticipated that the remaining work will be completed by the end of FY 2008, with no change in the total estimated cost of the project.
[d] Includes $110,000,000 for LHC supporting R&D and accelerator components to be fabricated by U.S. laboratories and $90,000,000 for purchases by CERN from U.S. vendors.

LHC Accelerator and Detector Funding Summary

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
LHC			
Accelerator Systems			
Operating Expenses	1,000	500	0
Capital Equipment	5,130	2,420	0
Total, Accelerator Systems	6,130	2,920	0
Procurement from Industry	23,200	18,527	0
ATLAS Detector			
Operating Expenses	4,280	3,076	1,642
Capital Equipment	4,710	2,413	1,598
Total, ATLAS Detector	8,990	5,489	3,240
CMS Detector			
Operating Expenses	4,450	2,054	1,300
Capital Equipment	6,030	3,510	2,900
Total, CMS Detector	10,480	5,564	4,200
Total, LHC	48,800	32,500	7,440

Changes have been made by each of the three U.S. projects, and approved by DOE project management, based on actual expenditures and progress during FY 2004, and updated planning based on the FY 2004 experience.

In FY 2006, funding will be used for completion of the fabrication of detector subsystems such as tracking chambers and data acquisition electronics.

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

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
• **Accelerator Systems**	**6,130**	**2,920**	**0**

All construction work including production of quadrupole magnets, cryogenic/electrical power feed boxes, and beam absorbers for the LHC beam interaction regions are scheduled to be completed in FY 2005 per the LHC project execution plan. Production testing of superconducting wire and cable for the LHC main magnets is also scheduled to be completed in FY 2005 per the plan. Funding is reduced to zero for FY 2006.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
• **Procurement from Industry**	**23,200**	**18,527**	**0**

Final funding will be provided in FY 2005 to support reimbursement to CERN for purchases from U.S. industry that included superconducting raw materials, superconducting wire, superconducting cable, cable insulation materials, and other technical components. Funding is reduced to zero for FY 2006.

• **ATLAS Detector**	**8,990**	**5,489**	**3,240**

In FY 2006, funding will primarily support the installation of U.S.-supplied equipment at CERN, namely the transition radiation tracker barrel, the tile calorimeter, the silicon inner tracker, and the muon drift test chambers. In addition, fabrication of the detector trigger and data acquisition system will continue. Funding is decreased by $2,249,000 to follow the ramp-down of detector fabrication.

• **CMS Detector**	**10,480**	**5,564**	**4,200**

In FY 2006, funding will primarily support the assembly and installation of U.S.-supplied equipment at CERN. Assembly of the hadron calorimeter and installation of electronics and readout boxes will continue at CERN. Endcap muon chambers will also be installed at CERN, and production of electronics for the electromagnetic calorimeter and the mechanics for the inner tracker will continue. Production assembly of the silicon detector layers will continue. Funding is decreased by $1,364,000 to follow the ramp-down of detector fabrication.

▪ **Large Hadron Collider Support**	**15,600**	**29,400**	**52,640**

The U.S. LHC Research program enters a critical phase in FY 2006 with final preparations for LHC turn-on in 2007. Significant increases in this area are planned for FY 2006 to meet the growing need for LHC support activities. The main use of the resources will be for LHC software and computing, and pre-operations for the U.S.-built systems that are part of the LHC detectors. The U.S. LHC effort is one of the high priority components of the HEP program and has been repeatedly endorsed by HEPAP.

Funding for pre-operations of the LHC detector subsystems built by U.S. physicists will increase significantly to $21,270,000 in FY 2006. The ramp-up in funding ($+9,368,000) will support the development and deployment of tools for control, calibration, and exploitation of detector data, including databases and remote detector monitoring and control systems. These tools will facilitate remote participation by U.S. physicists in the pre-startup activities at the LHC, ensuring proper commissioning and startup of U.S.-supplied components. U.S. CMS collaborators will be performing vertical integration tests of the major detector subsystems and using functional prototypes of the final data acquisition system in advance of their final installation in the underground cavern. U.S. ATLAS collaborators will be performing testing and commissioning of most detector subsystems. A small effort focused on R&D for specific possible LHC detector upgrades will continue.

Increased support will also be provided for technical coordination and program management during those crucial years, both at the participating U.S. national laboratories and at CERN. The U.S. LHC Accelerator Research Program will be conducting R&D towards possible future LHC accelerator

	FY 2004	FY 2005	FY 2006

(dollars in thousands)

upgrades ($10,999,000). This effort ramps-up significantly in FY 2006 ($+7,749,000) as fabrication begins on initial prototypes for upgraded LHC quadrupole magnets.

The LHC software and computing effort will enable U.S. physicists to analyze the vast quantity of LHC data in a transparent manner, and empower them to take a leading role in exploiting the physics opportunities presented by the LHC. The LHC Software and Computing program ($20,371,000) will enter a critical year in FY 2006, when the combination of software development, facilities hardware and support, and grid computing must come together to allow U.S. scientists to participate fully in the data challenges and analyses that will be conducted in preparation for the 2007 turn-on. In FY 2006, the U.S. effort will be focused on data challenges, where a significant fraction of the hardware needed for full LHC data analysis will be tested with professional-quality software on simulated data. These systems need to grow rapidly from prototypes to fully functional systems in 2006. The planned funding ramp-up in FY 2006 ($+6,123,000) 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 maintain the central role during data analysis that they played during detector fabrication. During this period, grid computing solutions will be integrated in the LHC computing model, allowing U.S. researchers full access to data and CPU needed to analyze the large and complex LHC dataset.

	FY 2004	FY 2005	FY 2006
▪ **AGS Operations/Support**	**650**	**650**	**637**

Operations at BNL for HEP experiments using the AGS facility were terminated at the end of FY 2002. Funding continues for close-out costs and long-term decontamination and decommissioning (D&D).

	FY 2004	FY 2005	FY 2006
▪ **Other Facilities**	**8,582**	**16,495**	**19,852**

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

Includes $1,624,000 for General Purpose Equipment and $4,065,000 for General Plant Projects at LBNL for landlord related activities.

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

	FY 2004	FY 2005	FY 2006
Total, Proton Accelerator-Based Physics	**382,634**	**401,120**	**387,093**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Research	
▪ In National Laboratory Research, a small decrease is reallocated to partially support high-priority facilities operations	-331

	FY 2006 vs. FY 2005 ($000)
▪ In University Service Accounts, a small increase supports university groups working at the Tevatron	+99
Total, Research	**-232**
Facilities	
▪ In Tevatron Complex Operations, the increase supports operations of the Tevatron complex, as effort shifts from Tevatron Complex Improvements (see below). This includes continued implementation of the Run II luminosity upgrades in Tevatron running according to the planned profile, as well as the first year of full operations for the NuMI/MINOS program using the Main Injector in fixed-target mode.	+6,170
▪ In Tevatron Complex Improvements, the decrease reflects reductions for Tevatron complex support and Technology R&D supporting projects. This includes a decrease of $10,250,000 as the effort on BTeV is terminated; this is offset by an increase of $3,935,000 in AIP, operations and R&D support as the effort to improve proton flux for the NuMI beam begins, and an increase of $1,456,000 in GPP to enhance site-wide infrastructure. A decrease of $550,000 is taken for the MINOS project as reflected in the approved profile; and a decrease of $16,080,000 in the Run II upgrades of the Tevatron complex, also follows the planned funding profile.	-21,489
▪ In the Large Hadron Collider project, the decrease reflects the revised funding profile consistent with the changes to the CERN LHC completion date and its impact on the U.S. portions of the LHC detector sub-projects. The total project cost is unchanged. The U.S. LHC accelerator funding ramps down as that project completes	-25,060
▪ In Large Hadron Collider Support, the increase is provided in part for significantly increased effort in providing the computing systems and networks needed to effectively handle and process the large volume of LHC data. The support for the detector pre-operations is also significantly increased, as detector testing and commissioning activities are ramping up quickly in 2006. A small accelerator R&D effort focused on LHC machine improvements also increases.	+23,240
▪ In AGS Operations/Support the small decrease reflects the cost of continued decommissioning of AGS experimental areas.	-13
▪ In Other Facilities, the increase is held pending completion of peer review and/or programmatic review. The extent of the increase is somewhat overstated because the FY 2005 funding level has already been reduced by programmatic decisions that have resulted in a reallocation of some of the FY 2005 funding from this activity.	+3,357
Total, Facilities	**-13,795**
Total Funding Change, Proton Accelerator-Based Physics	**-14,027**

Electron Accelerator-Based Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Electron Accelerator-Based Physics					
Research	27,030	25,457	24,865	-592	-2.3%
Facilities	117,935	118,472	107,957	-10,515	-8.9%
Total, Electron Accelerator-Based Physics	144,965	143,929	132,822	-11,107	-7.7%

Description

The mission of the Electron Accelerator-Based Physics subprogram is to foster fundamental research in high energy physics using electron accelerators that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Electron Accelerator-Based Physics subprogram utilizes accelerators with high-energy and ultra-accurate beams to create and investigate matter at its most basic level. It was the electron accelerator at SLAC that in the 1960's first identified the existence of quarks as the inner constituents of the proton and neutron. During the 1980's, electron accelerators – in tandem with proton machines – were instrumental in establishing the Standard Model as the precise theory of electromagnetic and weak interactions.

Over the last few years, the electron B-factory at SLAC has provided precision measurements of how matter and antimatter behave differently in the decay products of B-mesons. The measurement of "CP violation" is considered by physicists to be vital to understand why the universe appears to be predominantly matter, rather than an equal quantity of matter and anti-matter, one of the greatest puzzles we face in comprehending the universe. This subprogram addresses two of the six long-term indicators that contribute to the Program Goal and several of the key HEP questions identified in the Overview section above.

Supporting Information

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

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

Since 1999, the BaBar experiment at the SLAC B-factory has pursued a broad program of physics studies on particles containing bottom or charm quarks as well as other measurements that support or complement the CP violation program. The Belle experiment at the KEK-B accelerator in Japan has carried out a very similar program. A small number of U.S. university researchers participate in the Belle experiment. There has been regular cooperation as well as competition between the BaBar and Belle experiments that has led to a better understanding of results that are more precise. The CLEO-C experiment at the Cornell Electron Storage Ring (CESR) has been concentrating on certain precision measurements of particles containing charmed quarks that are difficult to do at the B-factory. These are used both for testing the theories used to interpret the CP violation measurements and as input to the physics analyses done at the B-factory.

Research and Facilities

The Research category in the Electron Accelerator-Based Physics subprogram supports the university and laboratory based scientists performing experimental research at electron accelerator facilities in the U.S. and abroad. Experimental research activities are collaborative efforts by research groups from LBNL, LLNL, SLAC, and about 40 colleges and universities, along with a large number of foreign research institutions, and include analysis and interpretation of data and publication of results. The university program also includes a small amount of funds at national laboratories (so-called "university service accounts") to allow university groups to perform specific tasks connected with the experimental research program.

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

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

Highlights

Recent accomplishments include:

- In FY 2004, the BaBar collaboration announced the first conclusive evidence of "direct CP violation" in B meson decays. This phenomenon is observed as a difference in the decay rates of B mesons (versus anti-B mesons) into the same final state, as opposed to the "indirect," time-dependent difference first seen in 1999. This effect is much larger than in the K meson system where CP violation was originally observed.
- Combined data from BaBar and Belle continue to show hints of possible new physics beyond the Standard Model in a class of B meson decays to particles (such as K mesons) which contain the strange quark. Current statistics are not sufficient to make a definitive measurement in any single decay mode and several related decays must be averaged to observe the effect. If the effect is real, it should be convincingly demonstrated (or ruled out) with approximately a factor of 2 increase in the total dataset for each experiment, which is expected to be accumulated by 2006.

- In 2004, the B-factory continued its impressive performance: PEP-II delivered over 100 fb^{-1}. Data collection continues at a high rate to improve the precision of the results, look for evidence in new modes, and resolve any discrepancies. Data collected to date are consistent with the current Standard Model description of CP violation, although there are possible indications of new physics in the data, as discussed above.

The major planned efforts in FY 2006 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 2006, this effort will focus on data taking with the upgraded accelerator and detector. The physics issues to be addressed include expanding our understanding of the matter-antimatter asymmetry in many particle decay modes and the origin of mass in the universe. This research program will conclude by FY 2008 at the latest.
- *The research program at other electron accelerator facilities*. This program complements the B-factory/BaBar efforts and consists of a group of experimental research activities using the CESR and the KEK-B electron accelerator facilities. A total of 4 U.S. university groups work at KEK-B, and 22 U.S. university groups work at CESR.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research..	**27,030**	**25,457**	**24,865**
▪ **University Research**	**16,157**	**15,500**	**15,500**

The university program consists of groups at about 40 universities doing experiments at electron accelerator facilities. These university groups analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; and train graduate students and post-docs. The current Electron Accelerator-Based Physics subprogram is focused on the study of charm and bottom quarks and the tau leptons that are all heavier than the particles of everyday matter and well suited for studying rare processes. The most interesting of these processes is CP violation that is needed to explain the fact that our universe is mostly made of matter and not antimatter. The BaBar experiment at the SLAC B-factory has been pursuing a broad program of physics studies on particles containing bottom or charm quarks with CP violation measurements and other measurements that support or complement the CP violation program.

U.S. university physicists 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.

The university program also supports nine groups that work at the CESR at Cornell University; and four groups that work at the KEK-B accelerator complex at KEK in Japan. The CLEO-C experiment at the CESR is concentrating on certain precision measurements of particles containing charmed quarks that are difficult to do at the B-factory. There is regular cooperation as well as competition between the SLAC and KEK experiments that has led to a better understanding of how to do the data

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

analysis leading to physics results that are more precise than they would be otherwise. University-based research efforts will be selected based on peer review.

In FY 2006, the university program is unchanged in order to continue support of operation of the detector and analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators. To the extent possible, the detailed funding allocations will take into account the involvement of university based research groups in the targeted physics research activities. These include research efforts related to the high priority experiments such as BaBar.

	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**10,614**	**9,697**	**9,055**

The national laboratory research program consists of groups at several laboratories participating in experiments at electron accelerator facilities with a physics program similar to the university program described above. In FY 2006, the laboratory experimental physics research groups will be focused mainly on supporting operations of the detector as well as analysis of the unprecedented amount of physics data generated by the B-factory and other electron accelerators. This effort decreases somewhat in FY 2006 as some laboratory groups move to other research areas.

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

The experimental research group from SLAC participates in all phases of the experiments. Because they are imbedded in the laboratory structure, they provide invaluable service in the upgrade, calibration and operation of the detector as well as reconstruction and analysis of the data.

The experimental research group at LBNL makes significant contributions to the physics analysis of the data and the software computing system needed to reconstruct the data into physics quantities used for analysis.

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

	FY 2004	FY 2005	FY 2006
▪ **University Service Accounts**...........................	**259**	**260**	**310**

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

	FY 2004	FY 2005	FY 2006
Facilities...	**117,935**	**118,472**	**107,957**
▪ **B-factory Operations**	**95,996**	**96,637**	**93,457**

Funding for operations, along with the additional $30,000,000 provided for SLAC linac operations in support of the Linac Coherent Light Source (LCLS) project by the Basic Energy Sciences (BES) program, (see the *Facilities* section of the BES Materials Science and Engineering subprogram) supports continued running of the accelerator and the operation of the BaBar detector for data collection for 5,200 hours. Including the operations support from BES, the increase in total operations funding over FY 2005 is needed to pay for longer running time along with significantly increased power costs. This marks the beginning of the transition of the SLAC linac to LCLS.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

The B-factory will be the priority HEP research program at SLAC in FY 2006. It is anticipated that the collected data will be about twice the amount collected in FY 2005 and will ensure a continuing U.S. leadership role in the program to study the excess of matter over antimatter in the universe. The funding includes full support for increases in power costs as well as computing support to analyze the collected data.

	FY 2004	FY 2005	FY 2006
B-factory Operations in hours	4,810	3,380	5,200

▪ **B-factory Improvements**	**21,939**	**21,835**	**14,500**

Funding is provided for accelerator and detector maintenance activities, repair and replacement of failing or obsolescent components, and minor improvements and upgrades ($3,075,000) to existing systems. In addition, an upgrade of the associated computing system ($2,500,000) is provided to handle the unprecedented data volumes being generated by the expected luminosity improvement of the B-factory. Also included is funding for the completion of the Major Item of Equipment, BaBar Instrumented Flux Return (IFR) Upgrade in FY 2006 according to the planned profile ($700,000; TEC and TPC of $4,900,000), and increased support for general site-wide infrastructure to ensure reliable and efficient operations by providing assistance with ES&H, infrastructure and maintenance needs ($8,225,000). The decrease in funding in FY 2006 reflects the completion of accelerator and detector upgrades ($-9,378,000) offset by an increase in GPP funding for infrastructure ($+2,043,000).

Total, Electron Accelerator-Based Physics	**144,965**	**143,929**	**132,822**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Research	
▪ In National Laboratory Research, the decrease reflects the move of some Electron Accelerator-Based Physics research groups to other research areas	-642
▪ In University Service Accounts, the increase supports university groups working at the B-factory	+50
Total, Research	**-592**

	FY 2006 vs. FY 2005 ($000)
Facilities	
▪ In B-factory Operations, the decrease reflects support for SLAC operations that is now provided by the Basic Energy Sciences program. Including the support from BES, total SLAC operations funding is increased ($+26,820,000) to pay for full B-factory operations while beginning the transition of the SLAC linac to LCLS	-3,180
▪ In B-factory Improvements, the decrease reflects the planned ramp down of the B-factory upgrades ($-7,790,000) and support ($-1,588,000); partially offset by the increased GPP funding ($+2,043,000) to assist with ES&H and infrastructure needs.	-7,335
Total, Facilities	**-10,515**
Total Funding Change, Electron Accelerator-Based Physics	**-11,107**

Non-Accelerator Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Non-Accelerator Physics					
University Research	13,565	12,750	12,750	0	0.0%
National Laboratory Research	18,820	17,120	17,120	0	0.0%
Projects	14,000	13,721	4,049	-9,672	-70.5%
Other	1,000	3,343	4,670	+1,327	+39.7%
Total, Non-Accelerator Physics	47,385	46,934	38,589	-8,345	-17.8%

Description

The mission of the Non-Accelerator Physics subprogram is to foster fundamental research in high energy physics using naturally occurring particles and phenomena that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Non-Accelerator Physics subprogram provides U.S. leadership in the study of those aspects of the fundamental nature of particles, forces and the universe that cannot be determined solely through the use of accelerators. These activities – including the search for or measurement of dark matter and dark energy – have the capability of probing the basic structure and composition of the universe not easily or directly accessible through accelerator-based experiments and provide complementary experimental data, new ideas and techniques. The research activities explore and discover the laws of nature as they apply to the basic constituents of matter and therefore align with the program mission on investigations of elementary particles and their interactions. This subprogram addresses two of the six long-term indicators that contribute to the Program Goal and several of the key HEP questions identified in the Overview section above.

Supporting Information

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

Research and Facilities

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

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

Highlights

Recent accomplishments include:

- Findings from the Sloan Digital Sky Survey (SDSS), along with NASA's Wilkinson Microwave Anisotropy Probe (WMAP) were named *Science* Magazine's "Discovery of the Year" in 2003 for their results on the properties of dark energy. Analysis and processing of SDSS data is supported by DOE and managed by Fermilab. WMAP, SDSS, and a new set of supernova observations released in FY 2004 are beginning to give scientists a handle on the way dark energy reacts to expansion or contraction of the universe.
- The Cryogenic Dark Matter Search (CDMS II) experiment completed and installed its full complement of towers of silicon and germanium detectors in the Soudan Mine in Minnesota in 2004 and the full experiment will take data until the end of 2005. Analysis of three months of data with one tower already provides the best results in the world to date on detection of dark matter particles.

The major planned efforts in FY 2006 are:

- *Fabrication of the VERITAS Telescope Array*. VERITAS is a planned new ground-based multi-telescope array that will study astronomical sources of high energy gamma rays, from about 100 GeV to about 50 TeV. This facility will complement the GLAST/LAT telescope which does the same physics up to about 100 GeV. Scientists are particularly interested in gamma rays from poorly-understood astronomical sources such as Active Galactic Nuclei and Gamma Ray Bursters, and searches for signatures of supersymmetric dark matter. The experimental technique was developed by the DOE/HEP-supported researchers at the Harvard-Smithsonian Whipple

Observatory on Mt. Hopkins in Arizona, and the new project is supported by a partnership between DOE, NSF and the Smithsonian Institution. Fabrication began in FY 2004 on Kitt Peak in Arizona and will be completed at the end of FY 2006.

- *Operation of the Pierre Auger Observatory*. The Pierre Auger Observatory is the world's largest area cosmic ray detector, covering about 3,000 square kilometers in Argentina, the goal of which is to observe, understand and characterize the very highest energy cosmic rays. The southern array will complete fabrication in 2005, and operations have already begun with the partially completed array. Full operations begin in 2006. This research program is being carried out by an international collaboration including scientists from U.S. universities, Fermilab, and institutions from 19 foreign countries. The U.S. part of the project is funded jointly with NSF and a significant contribution from the University of Chicago. Fermilab provides the project management team.
- *Operation of the Axion Dark Matter experiment (Stage I)* – This experiment, performed at LLNL, searches for "axions," particles that could explain the smallness of CP violation (matter-antimatter asymmetry) in strong interactions and at the same time account for the so-called "dark matter" in the universe. The previous experiment (AXION-I) set the world's best limits in the search for these hypothetical particles, and work on an upgrade to the experiment started in FY 2004. Data-taking will continue for three or four years. The upgraded experiment has greater sensitivity than AXION-I because of advanced signal amplifier electronics.
- *Preparations for launch of the LAT.* The LAT telescope fabrication will be completed at the end of FY 2005 and integration on the spacecraft has commenced. The LAT is the primary instrument to be flown on NASA's GLAST mission, scheduled for launch in 2007. Its goals are to observe and understand the highest energy gamma rays observed in nature and yield information about extreme particle accelerators in space, including Active Galactic Nuclei and Gamma Ray Bursters as well as search for dark matter candidates. This research program is being carried out by a collaboration, which includes particle physicists and astrophysicists from SLAC, NASA, NRL, U.S. universities, and institutions from Italy, France, Japan, and Sweden.
- *Preparations for launch of the AMS*. AMS is an international consortium experiment, led by MIT, to be placed on the International Space Station in 2008. Fabrication will be completed in 2005. It will measure cosmic rays in search of anti-matter in the universe, and will search for evidence of supersymmetric dark matter.
- *Research, development, and design for the SuperNova Acceleration Probe (SNAP) Experiment, a concept for the DOE/NASA Joint Dark Energy Mission (JDEM).* LBNL is leading an effort to develop this space-based dark energy experiment, designed to discover and precisely measure thousands of type Ia supernovae. The resulting data precisely probe the nature of dark energy, responsible for the accelerating expansion of the universe, as well as determining the history of accelerations and decelerations of the universe from the present back to approximately 10 billion years ago. The project and collaboration is led by LBNL and includes scientists from DOE laboratories, NASA centers, U.S. universities and foreign institutions.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
University Research..	**13,565**	**12,750**	**12,750**

The university program consists of groups at more than 35 universities doing experiments at Non-Accelerator Physics facilities, using ever more sophisticated techniques to probe fundamental physics questions using naturally occurring particles.

These university groups plan, build, execute, analyze and publish results of experiments; develop the physics rationale and preliminary designs for future experiments; develop new theoretical models and provide interpretations of existing experimental data; and train graduate students and post-docs.

University physicists in this research area often work in collaboration with other university and laboratory groups. University-based research efforts will be selected based on peer review.

In FY 2006, the university program in Non-Accelerator Physics will provide support for those universities involved in projects at the same level as FY 2005. Several new experiments (e.g., Pierre Auger, AMS, and GLAST/LAT) will have completed their fabrication phase and are moving in to deployment, commissioning, operations and data analysis. To the extent possible, the detailed funding allocations will take into account the discovery potential of the proposed research. One notable example is the AMS experiment, the goal of which is to detect sources of extra-galactic antimatter, using an instrument attached to the International Space Station. In FY 2006, the AMS collaboration will continue preparations for the planned 2008 launch. This project is led by scientists at MIT and consists of a collaboration among NASA, multiple U.S. universities, and numerous international institutions.

In FY 2006, the LAT telescope will be integrated into its spacecraft before its launch on the GLAST mission in 2007. This project is led by SLAC and consists of a collaboration among NASA institutions, U.S. universities and four international partners.

Other research efforts that will be continuing in this subprogram include: KamLAND, an underground neutrino oscillation detector which detects reactor-produced neutrinos in Japan; Super-Kamiokande, a proton decay, solar and atmospheric neutrino detector located in the Kamioka Underground Laboratory in Japan; CDMS-II in the Soudan Mine in Minnesota; VERITAS in Arizona; and R&D for the SNAP mission concept for a future DOE/NASA JDEM.

National Laboratory Research.........................	**18,820**	**17,120**	**17,120**

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

In FY 2006, the laboratory experimental physics research groups (including groups at LBNL, Fermilab and SLAC) will be focused mainly on supporting the spacecraft integration for the GLAST/LAT telescope and analysis of previous experimental data; research and development for the SNAP mission concept; and continued analysis of data from SDSS.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Projects	**14,000**	**13,721**	**4,049**

In FY 2006, this effort will be focused mainly on R&D for the SNAP mission concept, and fabrication of VERITAS; with the completion of the DOE contribution to GLAST/LAT fabrication in FY 2005, the overall effort in this category is significantly reduced.

The FY 2006 program for VERITAS ($1,149,000; TEC of $4,799,000; TPC of $7,399,000) will continue the fabrication phase for the full telescope array and complete this project.

The DOE contribution to GLAST/LAT fabrication (current TEC and TPC of $42,000,000) is completed in FY 2005; all pre-operations are covered under the Research categories above.

The FY 2006 SNAP program ($2,900,000) will focus on finalizing the research and development for technology needed to provide a mission concept for the future JDEM mission. Funding for JDEM fabrication has not been identified by DOE or NASA. Funding is sufficient to continue the detailed SNAP design and prototyping phase. DOE is actively engaged with NASA on JDEM. The recent National Science and Technology Council's Interagency Working Group on the Physics of the Universe report recommended that DOE and NASA develop JDEM.

Other	**1,000**	**3,343**	**4,670**

Includes funding for private institutions and other government laboratories and institutions that participate in Non-Accelerator Physics research. This category also includes funding for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities.

Total, Non-Accelerator Physics	**47,385**	**46,934**	**38,589**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Projects	
The decrease reflects a ramp down of $8,421,000 for GLAST/LAT fabrication and $901,000 for the VERITAS fabrication, both according to their planned profiles, and decreases of $300,000 in AMS pre-operations testing activities and $50,000 in SNAP R&D.	-9,672
Other	
The increase reflects funds held pending completion of peer review and/or programmatic review. The extent of the increase is somewhat overstated because the FY 2005 funding level has already been reduced by programmatic decisions that have resulted in a reallocation of some of the FY 2005 funding from this activity.	+1,327
Total Funding Change, Non-Accelerator Physics	**-8,345**

Theoretical Physics

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Theoretical Physics					
University Research	23,478	22,550	22,550	0	0.0%
National Laboratory Research	15,343	16,161	16,135	-26	-0.2%
SciDAC	5,000	5,000	5,000	0	0.0%
Other	5,612	5,284	5,418	+134	+2.5%
Total, Theoretical Physics	49,433	48,995	49,103	+108	+0.2%

Description

The mission of the Theoretical Physics subprogram is to foster fundamental research in theoretical high energy physics that will provide new insights into the basic constituents of matter and the forces between them, thereby advancing the DOE's strategic goals for science.

Benefits

The Theoretical Physics subprogram provides the vision and mathematical framework for interpreting, understanding, and extending the knowledge of particles, forces, space-time and the universe. It includes activities ranging from detailed calculations of the predictions of the Standard Model of elementary particles to the extrapolation of current knowledge to a new plane of physical phenomena and the identification of the means to experimentally search for them. The Theoretical Physics subprogram also includes a major effort to incorporate Einstein's theory of gravity and space-time geometry into a unified description of all the forces of nature and cosmology, to illuminate the origin and evolution of the universe. Because theoretical interpretation and analysis underpins almost all progress in HEP, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key HEP questions identified in the Overview section above.

Supporting Information

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

Research at Universities and National Laboratories

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

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

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

Scientific Discovery through Advanced Computing

The HEP program funds SciDAC programs in the areas of accelerator modeling and design (Advanced Computing for 21st Century Accelerator Science and Technology), theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (SciDAC Center for Supernova Research and Shedding New Light on Exploding Stars: TeraScale Simulations of Neutrino-Driven Supernovae and their Nucleosynthesis), and applying grid technology (Particle Physics Data Grid Collaborative Pilot). Each of these projects has made significant strides in forging new and diverse collaborations (both among different disciplines of physics and between physicists and computational scientists) that have enabled the development and use of new and improved software for large-scale simulations. Examples include the development of algorithms to solve the underlying algebraic equations for multidimensional radiation transport (for supernova simulations); the first complete three-dimensional calculation of the complete evolution of a core collapse supernova; the first parallel beam-beam simulation code that includes, in a single application, weak-strong and strong-strong models, finite crossing angle, longitudinal effects, and long-range collisions via a new shifted Green function algorithm; development of a full Applications Programming Interface (API) for running lattice gauge calculations on a variety of hardware platforms; and improvement and use of grid technology in running experiments.

Highlights

Recent accomplishments include:

- The 2004 Nobel Prize in Physics was awarded to three physicists for discovery of “asymptotic freedom” in the theory of strong interactions, Quantum ChromoDynamics (QCD). The research of two of them has been supported by the High Energy Physics program for many years.
- Observations of distant supernovae have indicated that the rate at which the Universe is expanding is actually accelerating, in contradiction to all expectations based on the attractive nature of the gravitational force. This discovery, which has been dubbed “dark energy”, has opened two lines of theoretical work. One is the attempt to characterize the new phenomenon in such a way that future observations can most meaningfully confirm or deny its reality. The second is the attempt to find what new kinds of fundamental forces could give rise to this new aspect of Nature.
- During the past year, the first high precision numerical simulation of the simplest strong interaction decay constants and mass differences, including the important but difficult “virtual quark” effects

was carried out. The agreement between the calculated and experimental values was about one percent. This is an improvement by nearly an order of magnitude over previous calculations and was accomplished by the application of new highly efficient algorithms combined with the use of today's supercomputers. Extending these simulations to more important quantities will require the new computers being planned for fabrication in FY 2005 and beyond. See first bullet below.

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 2006:

- *Lattice QCD*. Quantum ChromoDynamics (QCD) is a very successful theory that describes the strong interactions between quarks and gluons. Although the equations that define this theory are in principle exact, none of the analytical methods that are so successful elsewhere in theoretical physics are adequate to analyze it. The reason that QCD is so intractable is that it is a strongly coupled gauge field theory. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results. It has long been known that QCD can be analyzed to any desired precision by numerical methods, given enough computational power. Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made some QCD calculations feasible with quite high precision (one to two percent precision). Some of the computational tools for this effort are provided through the SciDAC program. Progress during FY 2006 will come from the major effort to fabricate the necessary computer hardware in partnership with the Nuclear Physics (NP) program and the Advanced Scientific Computing Research (ASCR) program.
- *Neutrino Phenomenology*. The accumulating evidence that neutrinos have mass raises a host of fundamental and timely questions: whether neutrinos might be their own anti-particles; whether there might be CP violation, or even CPT violation (the combination of CP-and Time-invariance violation), in the neutrino sector; the role of neutrinos in supernova explosions; and whether neutrinos might be the origin of the matter-antimatter asymmetry in the universe. In turn these questions have strong connections to astrophysics, cosmology, and other sectors of particle physics, so that new developments have wide-ranging impacts. New theories of neutrinos are being developed, and the active worldwide program of neutrino experiments can be expected to clarify this interesting domain of elementary particles.
- *New Ideas*. Theoretical physicists are speculating on whether there might be additional space dimensions that are normally hidden from us. It is even possible that some of these dimensions and their consequences are accessible to experiment, perhaps manifesting themselves in the production of mini-black holes at the LHC. Perhaps they can explain the nature of dark matter, or dark energy, or even suggest new cosmologies explaining the history and evolution of the universe.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
University Research...	**23,478**	**22,550**	**22,550**

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

In FY 2006, the university theory program will address problems across the full range of theoretical physics research. There is currently a "window of opportunity" to interpret and understand the exciting new physics results expected from the Fermilab Tevatron searching for new physics at the energy frontier, as described in previous sections. To the extent possible, the detailed funding allocations will take into account the involvement of university-based research groups in these targeted physics research activities.

National Laboratory Research	**15,343**	**16,161**	**16,135**

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

In FY 2006, the laboratory theoretical research groups will address problems across the full range of theoretical physics research, including the analysis and interpretation of the new data expected from both the Tevatron Collider detectors, CDF and D-Zero, and the B-factory's detector, BaBar.

SciDAC	**5,000**	**5,000**	**5,000**

In FY 2006 there will be three principal continuing HEP SciDAC efforts: in the areas of advanced accelerator beam simulations, which support the accelerator development efforts for the Linear Collider, as well as optimizing performance for the Tevatron; platform-independent software to facilitate large-scale QCD calculations (see also below); and, very large scale, fault-tolerant data handling and "grid" computing that can respond to the serious data challenges posed by modern HEP experiments. We also expect a new solicitation for SciDAC proposals in FY 2006 to build on or enhance these pioneering software efforts.

Other	**5,612**	**5,284**	**5,418**

This category includes funding for the Lattice QCD Computer Program, as well as for education and outreach activities, compilations of HEP data and reviews of data by the Particle Data Group at LBNL, conferences, studies, workshops, funding for research activities that have not yet completed peer review, and responding to new and unexpected physics opportunities.

A joint effort with the Nuclear Physics (NP) and Advanced Scientific Computing Research (ASCR) programs is aimed toward the development of a ~5 Teraflops prototype computer by the end of FY 2005, using the custom QCD On-a-Chip (QCDOC) technology. This platform will enable U.S.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

researchers to stay competitive with other worldwide efforts in computational QCD research while developing a larger-scale hardware platform. Continuing the joint effort with NP, development of large-scale facilities (~20 Teraflops) will begin in FY 2006 for providing computing capabilities based on the most promising technology. This effort will be captured in a single Major IT investment.

In each year of the Lattice QCD IT investment, fabrication of computers employing the most cost-effective option will be undertaken. Given current projections of price performance for this kind of high-performance computing, the HEP contribution to this effort in FY 2006 of $2,000,000 will correspond to an additional ~3 Teraflops of sustained computing performance deployed, in addition to the 5 Teraflops already available from the QCDOC prototype by that time.

Several key R&D activities carried out from FY 2003 through FY 2005 have enabled this program. One is the successful completion and implementation of the uniform software environment on two types of parallel computer platforms developed for this program under SciDAC. Another is the completion and commissioning of the 5 Teraflops prototype QCDOC computer at BNL in FY 2005. A third is the program of design and optimization of commercial cluster computers carried out jointly with the Nuclear Physics program at Fermilab and the Thomas Jefferson National Accelerator Facility (TJNAF).

In FY 2006, a program of the most important and accessible research computations on the QCDOC computer at BNL will continue and is expected to yield high precision calculations of parameters that are needed to interpret current experiments at the SLAC B-Factory. These calculations are expected to reduce the theoretical uncertainty in interpreting experimentally measured quantities by up to a factor of 2.

This category also includes support for the QuarkNet education project ($775,000). This project takes place in QuarkNet "centers" which are set up at universities and laboratories around the country. Each center has 2 physicist mentors and, over 3 years, goes through several stages to a full operating mode with 12 high school teachers. The project began in 1999 with an initial complement of 12 centers starting in the first of three yearly stages of development. The full complement of 60 centers, with 720 teachers, will be in place in FY 2004. In FY 2005, 10 of these centers will still be at stage 2, with the rest in full operations mode. The project plans to ramp-up to its planned steady-state level of 60 fully operating centers in FY 2006. The operations will continue through the life of the LHC program at CERN.

Total, Theoretical Physics	**49,433**	**48,995**	**49,103**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
National Laboratory Research	
The small decrease is reallocated to partially support increased costs in facilities operations	-26

	FY 2006 vs. FY 2005 ($000)
Other	
The increase is primarily for the Quarknet education project	+134
Total Funding Change, Theoretical Physics	**+108**

Advanced Technology R&D

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Advanced Technology R&D					
Accelerator Science	23,316	27,335	27,165	-170	-0.6%
Accelerator Development	39,660	35,825	42,125	+6,300	+17.6%
Other Technology R&D	16,351	13,698	18,852	+5,154	+37.6%
SBIR/STTR	0	17,863	18,184	+321	+1.8%
Total, Advanced Technology R&D	79,327	94,721	106,326	+11,605	+12.3%

Description

The mission of the Advanced Technology R&D subprogram is to foster fundamental research into particle acceleration and detection techniques and instrumentation. These in turn provide enabling technologies and new research methods to advance scientific knowledge in a broad range of energy-related fields, including high energy physics, thereby advancing the DOE's strategic goals for science.

Benefits

The Advanced Technology R&D subprogram provides the technologies needed to design and build the accelerator, colliding beam, and detector facilities used to carry out the experimental program essential to accomplishing the programmatic mission in high energy physics. This is accomplished by supporting proposal driven, peer reviewed research in the fundamental sciences underlying the technologies used for HEP research facilities with a particular focus on new concepts and inventions and in the reductions of these new concepts and inventions to practice; that is, developing the new technologies to the point where they can be successfully incorporated into construction projects whose performance will significantly extend the research capabilities beyond those that currently exist. Because accelerator and detector R&D underpins almost all progress in HEP, this subprogram addresses all of the six long-term indicators that contribute to the Program Goal and all of the key HEP questions identified in the Overview section above.

Supporting Information

High Energy particle physics research remains now, and for the foreseeable future, strongly dependent on the use of high energy particle beams provided by charged particle accelerators, storage rings, and their associated detectors. Operating in the extreme domains essential for successful particle physics research demands very specialized technology that takes substantial time and expense to invent, design, build, maintain and upgrade. The R&D programs that support such technology development are unavoidably costly and long term.

Since few of the core technologies used in high energy physics research are directly marketable, industry has no motivation to develop the necessary expertise or to do the essential R&D. Consequently, the DOE HEP program has supported a very successful program of technology R&D that has ensured the availability of the most technically advanced research facilities and a world-class U.S. HEP program. Since in many cases these same technologies find applications to synchrotron light sources, intense neutron sources, very short pulse-high brightness electron beams, and computational software for accelerator and charged particle beam optics design, the applications are used in nuclear physics, materials science, chemistry, medicine, and industry.

The High Energy Physics Advisory Panel (HEPAP), consisting of leading members of the high energy physics community, provides advice to the DOE and the NSF on a continuing basis regarding the direction and management of the national high energy physics research program. Their 2002 long range planning report identified an accelerator that collides electrons and positrons at a center-of-mass energy of 500 GeV or higher (a "Linear Collider") as the highest priority next research facility for high energy physics. A similar endorsement has come from the European Committee on Future Accelerators and from the Asian Committee on Future Accelerators.

In 2003, SC prepared a list of major science facilities that could be built over the next 20 years to maintain a leading U.S. scientific program of research. The list divides the needs into near term, midterm and long term. The Linear Collider is identified as the highest priority item for SC in the midterm.

Active world-wide, inter-regional cooperation on linear collider accelerator systems, physics studies, and detector development has been underway for the past decade or more. Central to this cooperation is the International Committee on Future Accelerators (ICFA). ICFA was created in 1976 by the International Union of Pure and Applied Physics for the purpose of facilitating International collaboration in the construction and use of accelerators for high energy physics research. In 2003, ICFA formed the International Linear Collider Steering Committee (ILCSC) to coordinate scientific, technical, and governmental aspects of the activities leading to an international proposal to construct a linear collider. Also in 2003, three groups were created to interface national R&D programs with the ILCSC. They are the U.S. Linear Collider Steering Group (USLCSG), created by HEPAP, the European Committee on Future Accelerators (ECFA), and a similar group in Asia created by the Asian Committee for Future Accelerators (ACFA). Since its formation, the ILCSC has been coordinating the activities of the three regional groups in the process of establishing a standard set of linear collider operating parameters, establishing a technology recommendation process, and exploring the organization of an international design team.

In August 2004, after 8 months of careful deliberation, the International Technology Recommendation Panel (ITRP) convened by the ILCSC, selected the superconducting radiofrequency (cold) technology as the preferred technology for building an international linear collider. ICFA unanimously endorsed the recommendation.

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

Accelerator Science

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

Accelerator Development

The larger task of reducing new concepts and technical approaches to the stage of proven engineering feasibility, so that they can be incorporated into existing or new facilities, is done under Accelerator Development. When concepts develop enough to be viewed as part of a larger system or as leading to a possible future proposal for a construction project, they are given special attention. The Linear Collider is the current R&D activity in this special category. Also included in this category is work on developing very high field superconducting magnet technology, studies of very high intensity proton sources for application in neutrino physics research, muon accelerator proof-of-principle research, and R&D in support of possible future upgrades at the LHC.

Other Technology R&D

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

Highlights

Recent accomplishments include:

- Researchers continue to make evolutionary progress in high field magnets for the next generation of both electron and hadron colliders. An industry-based R&D program funded by ATRD has provided production quantities of niobium-tin (Nb_3Sn) superconducting material in 2003 with a world record current density of over 3,000 amps per square millimeter at 12 Tesla. In addition to enabling R&D on very high field magnets for accelerators and storage rings, this material opens the way for the industrial development of very high-resolution magnetic resonance imaging (MRI) devices operating at 1gigahertz.
- Work at the national laboratories and at universities has shown interesting approaches in the fabrication of very high field accelerator magnets that address the engineering challenges of working with superconducting materials like niobium-tin and the high temperature superconductors. One of these has used the new niobium-tin material to demonstrate a dipole magnet with a central field of 16 Tesla, a new world record, and opening a path to the eventual doubling of the LHC's beam energy from 7 TeV to 14 TeV.
- Progress has been made on alternate methods of charged particle acceleration. In particular, current experiments at SLAC address the potential feasibility of a plasma-based “afterburner” that could potentially double the energy of a linear collider in only a few meters of plasma. Accelerating gradients of greater than 4 GeV per meter have been measured, and the acceleration of positrons (anti-electrons) by particle driven plasma wakefields has also been demonstrated, an essential step if the plasma accelerators are to ever be applied to electron-positron colliders.

The major Advanced Technology R&D efforts in FY 2006 are:

- *The Accelerator Science Research Program*. This program supports studies in scientific topics such as laser and radiofrequency (RF) driven acceleration, plasma-based accelerators, alternative radiofrequency accelerating structures, ionization cooling of muon beams, superconducting material development and applications, and nonlinear dynamics and chaos. This research is performed at about 27 universities and 6 DOE national laboratories (ANL, BNL, LANL, LBNL, Princeton Plasma Physics Laboratory [PPPL], and SLAC), and 2 Federal laboratories (NRL and National Institute of Standards and Technology [NIST]). The programs of research at the universities and national laboratories are complementary, and collaboration between the laboratories and the university research groups is strongly encouraged.
- *The Research and Development Program in General Technology R&D.* A component of the technology R&D at BNL, Fermilab, LBNL, and SLAC is focused on "reduction to practice" of new ideas and in general areas of technology important to the future research programs at that laboratory but not directly relevant to an operating facility or a new facility under construction. The principal activities funded are R&D on advanced superconducting magnets with a particular emphasis on reaching dipole fields above 18 Tesla and quadrupole fields approaching 300 Tesla per meter, development of an ultra high-intensity neutrino beam facility, RF acceleration systems for gradients above 75 megavolts per meter, new beam instrumentation, particle beam "cooling" techniques (particularly muon cooling), high intensity muon production targets, and advanced computation and computer modeling techniques.
- *Support for Linear Collider R&D.* A TeV scale linear electron-positron collider has been identified by the international high energy particle physics community, including various national laboratories, international advisory committees, and HEPAP, as an essential international facility to extend particle physics research beyond what is feasible at the LHC. In the U.S., the national collaboration will be reoriented and expanded to support R&D and design activities on a machine using the cold radio frequency accelerating structure recommended by the ITRP. In FY 2006 the R&D industrialization and related activities will be considerably expanded and internationalized. The support for a linear collider is, consequently, significantly expanded in FY 2006 to support the larger international R&D program.
- *Neutrino Physics R&D.* In FY 2006 we are initiating a broad-based effort to develop new accelerator and detector technologies that will be needed to address research opportunities in neutrino physics that have recently become accessible. The fundamental properties of neutrinos may shed light on how all the forces of nature unify into one, or why there is an abundance of matter over anti-matter in the universe. But the very weak interactions with ordinary matter that make neutrinos such useful probes also make them very hard to detect, so new detector technologies and higher intensity accelerators will be needed.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Accelerator Science	**23,316**	**27,335**	**27,165**
▪ **University Research**	**9,547**	**10,350**	**10,350**

In FY 2006, funding will provide for a program of accelerator physics and related technologies at about 27 universities at the same level as FY 2005. The research program includes development of new applications of niobium-tin and similar superconductors as well as high temperature superconductors; investigations of the use of plasmas and lasers to accelerate charged particles; development of novel high power RF sources for driving accelerators; development of advanced particle beam instrumentation; theoretical studies in advanced beam dynamics, including the study of non-linear optics; space-charge dominated beams and plasmas; and development of new computational and simulation methods and programs. Accelerator R&D into the fundamental issues associated with the ionization cooling of muon beams is included in this effort. University based research programs are selected based on review by well-qualified peers, and progress is monitored through a system of formal site visits, presentations at appropriate workshops, participation in conferences, and publications.

▪ **National Laboratory Research**	**12,339**	**15,328**	**15,219**

There are areas of Accelerator Science research that require the more extensive or specialized research facilities located at DOE national laboratories. Funding for this work is provided to six national laboratories, ANL, BNL, LANL, LBNL, PPPL, and SLAC. National laboratory research efforts are selected based on review by appropriate peers, laboratory program advisory committees, and special director-appointed review committees. Measurement of progress includes the annual HEP program review supported by well-qualified peers, publications in professional journals, and participation in conferences and workshops. Part of the funding included in this area supports R&D into high-power target studies required for possible future neutrino facilities, including for example, possible upgrades to the NuMI beam, and into support of muon ionization cooling studies, and in particular the international Muon Ionization Cooling Experiment (MICE) at Rutherford Laboratory in the UK.

BNL ($3,360,000) is the home of the very successful Accelerator Test Facility (ATF), supporting research that HEP funds at universities and in industry (particularly through the SBIR Program). In FY 2006, the ATF will continue a program of testing advanced accelerator concepts, developing new instrumentation, and developing next generation high brightness electron sources based on laser-driven photocathodes. R&D on muon ionization cooling will also be carried out.

The Center for Beam Physics at LBNL ($4,443,000) is supported in FY 2006 for research in laser-driven plasma acceleration, advanced RF systems, laser manipulation and measurement of charged particle beams, and a broad program in instrumentation development, accelerator theory, and computation. R&D on muon ionization cooling and theoretical studies of alternative muon acceleration schemes will also be carried out.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

An advanced accelerator R&D program is supported at SLAC ($4,000,000) in FY 2006 to explore particle-driven plasma accelerators, direct laser acceleration of electrons in vacuum, ultra high-frequency microwave systems for accelerating charged particles, very advanced electron-positron collider concepts, and theoretical studies in advanced beam dynamics methods and new computer computation and simulation codes. Much of the work on advanced accelerator concepts at SLAC is done in collaboration with universities funded by the ATRD subprogram.

Other activities ($3,416,000) supported in FY 2006 include: theoretical studies of space-charge dominated beams at PPPL; research on new means of generating high-brightness electron beams, and the use of charged particle wakefields to generate microwaves for particle acceleration at ANL; and development and maintenance of accelerator beam simulation codes at LANL.

	FY 2004	FY 2005	FY 2006
▪ **Other**	**1,430**	**1,657**	**1,596**

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

	FY 2004	FY 2005	FY 2006
Accelerator Development.................................	**39,660**	**35,825**	**42,125**
▪ **General Accelerator Development**.............	**15,600**	**13,225**	**17,125**

This research includes R&D to bring new concepts to a stage of engineering readiness where they can be incorporated into existing facilities, used in upgrading existing facilities, or applied to the design of new facilities. The work is almost entirely done at BNL, Fermilab, LBNL and SLAC. The major areas of R&D are superconducting magnet and related materials technology; high-powered RF acceleration systems; instrumentation; stochastic and electron cooling technologies; beam dynamics, both linear and nonlinear; and development of large simulation programs. Funding in this category increases in FY 2006 to support R&D directed towards developing a next-generation accelerator neutrino facility for the next decade that can significantly expand on the physics program begun with NuMI/MINOS.

Work at BNL in FY 2006 will focus on superconducting magnet R&D and related advanced materials development. R&D in support of high intensity muon production targets is also included in the BNL program. The R&D program at Fermilab in FY 2006 will address a broad spectrum of technology needs for that facility, including development of an ultra high-intensity neutrino facility, development of a superconducting RF module test facility, advanced superconducting magnet R&D, electron cooling, advanced beam instrumentation, and simulation codes to provide improved modeling of all aspects of Tevatron operations. Pre-conceptual R&D in support of an international muon ionization cooling experiment, a collaboration with Rutherford Appleton Laboratory in the UK, is also included. The LBNL R&D supported in FY 2006 includes work on very high field superconducting magnets using niobium-tin and possibly niobium-aluminum, on development of superconducting wire and cable in collaboration with U.S. industry for the national program in magnet R&D, on new beam instrumentation for use at Fermilab and SLAC, and on extensive beam dynamics and simulation studies with particular emphasis on electron cloud and related efforts in proton and electron colliders. The FY 2006 program at SLAC encompasses high-powered RF

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

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.

	FY 2004	FY 2005	FY 2006
▪ **Linear Collider**	**19,600**	**22,600**	**25,000**

The need for an electron-positron linear collider as a complement to and precision augmentation of the research program that will be carried out at the LHC now under construction at CERN was reviewed in 2001 by the International Committee of Future Accelerators (ICFA), the European Committee on Future Accelerators (ECFA), and the Asian Committee on Future Accelerators (ACFA) and HEPAP. These bodies have all identified a TeV-scale linear collider as the highest priority facility following the LHC to address the broad range of crucial, unresolved physics questions central to high energy physics.

The accomplishment of the international R&D program was to demonstrate that there are two principal, viable technical approaches to constructing a high energy linear collider. One of these approaches, developed by an international collaboration led by the German high energy physics laboratory, Deutsches Elektronen-Synchrotron (DESY), is based on the use of a superconducting RF acceleration system cooled to approximately 456 degrees Fahrenheit below 0. As noted previously, the ITRP has recommended this technology as the most suitable technology to provide the performance needs for the linear collider.

In FY 2005, a new international group is being put in place to coordinate and direct the international R&D program. The organization of this group and its management relationships to the three regional groups, in Asia, Europe and the U.S., will be based on the recommendations made by a task force set up by the ILCSC. The responsibilities of the international management team include a detailed review of the R&D, pre-conceptual design work, technical reviews for the chosen technology, and preparation of a consolidated design and design report. The pre-conceptual design which is not site-specific at this time will be used to develop a detailed R&D plan, industrialization plan, procurement plan, cost estimate, and schedule that is resource loaded and based on what is known about the scheduling of completion of pieces of the linear collider during construction. A detailed set of site requirements will also be developed and published.

In the U.S., a research collaboration will participate in preparing the consolidated design and the detailed R&D and industrialization activity planning. The U.S. collaboration will also layout and present a plan to the DOE and NSF on the R&D work that the U.S. will carryout as part of the international R&D team. It is anticipated that the U.S. linear collider activity will be jointly managed by the DOE and the NSF.

In FY 2006, all of the activities begun in FY 2005 to support development of a "cold" technology international design for the linear collider facility will be in force. The increase in U.S. linear collider funding from $22,600,000 in FY 2005 to $25,000,000 in FY 2006 will be essential for completing the reorganization of the U.S. linear collider collaboration to support the cold technology design and increased participation in the international collaborative activities.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **Muon Accelerators**	**4,460**	**0**	**0**

In FY 2003, this R&D effort was reviewed as part of a HEP long range planning exercise. As a result of this study, and recent future facilities planning undertaken by HEPAP, it was recognized that the work should be restructured to reflect the longer range nature of this R&D and the need to demonstrate the necessary technologies before committing to the more extensive work that would form the basis for proposing any new facility. Thus, this effort was redirected in FY 2005 into the Accelerator Science category while the necessary R&D is done to show that technical obstacles to producing and controlling high-intensity muon beams can be overcome.

Other Technology R&D	**16,351**	**13,698**	**18,852**
▪ **Advanced Detector Research**	**930**	**1,000**	**1,594**

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 foreseen but not yet approved experiments. Approximately six to eight grants a year are awarded through a competitive peer review program. This program complements the detector development programs of the national laboratories.

▪ **Detector Development**	**15,421**	**12,698**	**13,356**

New experiments frequently depend on advancements in technologies. This funding supports detector development work at the national laboratories and universities to advance these technologies to a point where there is reasonable chance that an experiment can adopt the technology successfully; one current area of investigation is R&D on detector technologies that could be used at a future Linear Collider. In FY 2006, this research area is slightly increased to augment development of new detectors and technologies that will be required to pursue new opportunities in particle astrophysics or at future accelerators (see also “Other” below).

▪ **Other**	**0**	**0**	**3,902**

This category includes funding for research activities that have not yet completed peer review, and to respond to new and unexpected physics opportunities. In FY 2006, these efforts are funded to develop new accelerator and detector concepts related to neutrino physics. A joint report of the HEP/NP neutrino physics community outlining the most promising future research directions in neutrino physics was released in Fall 2004 and will help inform the decision on which research directions to pursue.

SBIR/STTR	**0**	**17,863**	**18,184**

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.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

The organization of the topics and the annual solicitations for suggestions for R&D to be included in the annual solicitation are treated as an important and integral component of the advanced accelerator R&D program and selections of grants are made based on a combination of the recommendations of the peer reviewers and the importance to the HEP programs in Accelerator Science and Accelerator Development. In FY 2004, $15,590,000 was transferred to the SBIR program and $1,871,000 was transferred to the STTR program.

	FY 2004	FY 2005	FY 2006
Total, Advanced Technology R&D	**79,327**	**94,721**	**106,326**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Accelerator Science	
The small decrease is redirected to partially support increases in General Accelerator Development	-170
Accelerator Development	
▪ The increase is provided to advance R&D directed towards developing a next-generation accelerator neutrino facility	+3,900
▪ The increase is provided to accelerate the pace of Linear Collider R&D and provide leadership to the international R&D effort	+2,400
Total, Accelerator Development	**+6,300**
Other Technology R&D	
▪ **Advanced Detector R&D**	
The increase is provided for increased university involvement to bring to the prototype stage new detector technologies so that they can be investigated in the detector development programs	+594
▪ **Detector Development**	
The increase provides for additional support of R&D for new detectors needed for future accelerators	+658
▪ **Other**	
The increase is provided to develop new accelerator and detector concepts related to neutrino physics	+3,902
Total, Other Technology R&D	**+5,154**

	FY 2006 vs. FY 2005 ($000)
SBIR/STTR	
The increase reflects the mandated funding for the SBIR and STTR programs	+321
Total Funding Change, Advanced Technology R&D	**+11,605**

Construction

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Construction					
Neutrinos at the Main Injector (NuMI)	12,426	745	0	-745	-100.0%

Description

This provides for the construction of major new facilities needed to meet the overall objectives of the High Energy Physics program.

Benefits

The construction of the Neutrino at the Main Injector (NuMI) as a new facility at the Fermi National Accelerator Laboratory will enable decisive and controlled measurements of basic neutrino properties, including neutrino oscillations with a high flux beam of neutrinos in the energy range of 1 to 40 GeV. The study of the basic neutrino properties will provide important clues and constraints to the theory of matter and energy beyond the Standard Model.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Neutrinos at the Main Injector (NuMI)	**12,426**	**745**	**0**

This project provides for the construction of new facilities at Fermilab that are specially designed for the study of the properties of the neutrino and in particular to search for neutrino oscillations. Completion of this project is scheduled for FY 2005.

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Neutrinos at the Main Injector (NuMI)	
Decrease reflects project completion in FY 2005.	-745

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	13,726	18,791	22,290	+3,499	+18.6%
Accelerator Improvements Projects	9,401	7,085	2,375	-4,710	-66.5%
Capital Equipment	69,450	72,047	39,837	-32,210	-44.7%
Total, Capital Operating Expenses	92,577	97,923	64,502	-33,421	-34.1%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Unappro-priated Balance
98-G-304 Neutrinos at the Main Injector	109,162	95,991	12,426	745	0	0

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Acceptance Date
Large Hadron Collider — Machine	110,000	90,252	82,702	5,130	2,420	0	FY 2005
Large Hadron Collider — ATLAS Detector	102,950[a]	54,099	44,532	4,710	2,413	1,598	FY 2008
Large Hadron Collider — CMS Detector	147,050[b]	71,789	58,099	6,030	3,510	2,900	FY 2008
MINOS	60,272	44,510	41,960	2,000	550	0	FY 2005
GLAST/LAT	42,000[cd]	42,000[d]	25,679	7,900	8,421	0	FY 2006
Cryogenic Dark Matter Search (CDMS)	9,090[e]	4,908	4,358	550	0	0	FY 2004
Auger	4,730[f]	3,230	2,230	1,000	0	0	FY 2004
Run IIb D-Zero Detector	12,502[g]	12,502	6,252	2,542	3,708	0	FY 2007
Run IIb CDF Detector	10,374[h]	10,374	6,969	1,673	1,732	0	FY 2007
VERITAS	7,399[i]	4,799	0	1,600	2,050	1,149	FY 2006
BaBar Instrumented Flux Return (IFR) Upgrade	4,900	4,900	0	3,000	1,200	700	FY 2006
BTeV	6,750	6,750[j]	0	0	6,750	0	N/A
Total, Major Items of Equipment				36,135	32,754	6,347	

[a] The total U.S. contribution (TPC) for this project is $163,750,000, including $60,800,000 from NSF.
[b] The total U.S. contribution (TPC) for this project is $167,250,000, including $20,200,000 from NSF.
[c] The total TPC for this project is $136,600,000, including $93,400,000 from NASA and $1,200,000 from Japan.
[d] We expect a rebaselining of the GLAST/LAT project to be completed during the second quarter of FY 2005, possibly resulting in a new TEC and TPC for the DOE contribution of no more than $45,000,000. This change will not affect the scheduled FY 2005 completion date for DOE's portion of the GLAST project.
[e] The total TPC for this project is $18,390,000 including $9,300,000 from NSF.
[f] The total U.S. contribution (TPC) for this project is $8,680,000 including $3,950,000 from NSF.
[g] The total TPC for this project is $19,926,000, including $3,068,000 from NSF and $4,356,000 from foreign partners.
[h] The total TPC for this project is $13,545,000 including $3,171,000 from foreign partners.
[i] The total TPC for this project is $17,534,000 including $7,333,000 from NSF, $2,000,000 from the Smithsonian Institution, and $802,000 from foreign partners.
[j] The TEC for this project has been decreased to $6,750,000 from the range of estimate $187,000,000 to $221,000,000 reflecting the termination of the project after the engineering design phase in FY 2005.

Nuclear Physics

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Nuclear Physics					
Medium Energy Nuclear Physics	118,854	125,875	-1,044[a]	124,831	111,660
Heavy Ion Nuclear Physics	161,451	175,933	-1,383[a]	174,550	161,879
Low Energy Nuclear Physics	71,053	76,567	-585[a]	75,982	68,537
Nuclear Theory	28,434	29,665	-250[a]	29,415	26,665
Subtotal, Nuclear Physics	379,792	408,040	-3,262	404,778	368,741
Construction	0	0	0	0	2,000
Total, Nuclear Physics	379,792[b]	408,040	-3,262	404,778	370,741

Public Law Authorizations:

Public Law 95-91, "Department of Energy Organization Act"

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

Mission

The mission of the Nuclear Physics (NP) program is to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy and develop the scientific knowledge, technologies and trained workforce that are needed to underpin the Department of Energy's missions for nuclear-related national security, energy, and environmental quality. The program provides world-class, peer-reviewed research results and operates user accelerator facilities in the scientific disciplines encompassed by the Nuclear Physics mission areas under the mandate provided in Public Law 95-91 that established the Department.

Benefits

SC's Nuclear Physics program will substantially advance our understanding of nuclear matter and the early universe. It will help the United States maintain a leading role in nuclear physics research, which has been central to the development of various technologies, including nuclear energy, nuclear medicine, and the nuclear stockpile. Highly trained scientific/technical personnel in fundamental nuclear physics is another important result of the program. This valuable human resource is essential for many applied fields, such as nuclear medicine, space exploration, and national security.

Strategic and Program Goals

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

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[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.

[b] Includes reductions of $2,307,000 rescinded in accordance with P.L. 108-137 the Consolidated Appropriations Act, 2004, $8,778,000, which was transferred to the SBIR program, and $1,053,000, which was transferred to the STTR program.

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

Program Goal 05.20.00.00 - Explore Nuclear Matter, from the Quarks to the Stars — Understand the evolution and structure of nuclear matter, from the smallest building blocks, quarks and gluons, to the stable elements in the Universe created by stars; to unique isotopes created in the laboratory that exist at the limits of stability and possess radically different properties from known matter.

Contribution to Program Goal 05.20.00.00 Explore Nuclear Matter, from the Quarks to the Stars

The Nuclear Physics subprograms (Medium Energy, Heavy Ion, Low Energy, and Nuclear Theory) contribute to Program Goal 05.20.00.00 by supporting innovative, peer-reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, and in particular, to investigate the fundamental forces that hold the nucleus of the atom together, and determine the detailed structure and behavior of atomic nuclei. The program builds and supports world-leading scientific facilities and state-of-the-art instruments necessary to carry out its basic research agenda. Scientific discoveries at the frontiers of Nuclear Physics further the nation's energy-related research capacity, which in turn, provide for the nation's security, economic growth and opportunities, and improved quality of life. In developing strategies to pursue these exciting research opportunities, the Nuclear Physics program is guided by the long range planning report prepared by its primary advisory panel: Nuclear Science Advisory Committee (NSAC) - Opportunities in Nuclear Science (2002), and by the program's cognizance of opportunities expressed elsewhere; e.g., Connecting Quarks with the Cosmos (2003), a report prepared by the National Research Council and sponsored by DOE, the National Science Foundation (NSF), and National Aeronautics and Space Administration (NASA), and the interagency response to this report The Physics of the Universe, a Strategic Plan for Federal Research at the Intersection of Physics and Astronomy, prepared by the National Science and Technology Council. The program is consistent with both the DOE and SC Strategic Plans and with SC 20-Year Facility Plan.

The Medium Energy subprogram will contribute to Program Goal 05.20.00.00 by investigating the quark and gluon substructure inside the nucleon. Although protons and neutrons can be separately observed, their quark constituents cannot be, because normally they are permanently confined inside the nucleons. Measurements are carried out primarily using electron beams at the Thomas Jefferson National Accelerator Facility (TJNAF) and polarized proton collisions at the Relativistic Heavy Ion Collider (RHIC). The following indicator establishes a specific long-term goal in World-Class Scientific Research Capacity that the Nuclear Physics program is committed to, and progress can be measured against:

- making precision measurements of fundamental properties of the proton, neutron, and simple nuclei for comparison with theoretical calculations to provide a quantitative understanding of their quark substructure.

The Heavy Ion subprogram will contribute to Program Goal 05.20.00.00 by searching for the expected quark-gluon plasma 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 will 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. The following indicator establishes a specific long-term goal in World-Class Scientific Research Capacity that the Nuclear Physics program is committed to, and progress can be measured against:

- searching for, and characterizing the properties of, the quark-gluon plasma by briefly recreating tiny samples of hot, dense nuclear matter.

The Low Energy subprogram will contribute to Program Goal 05.20.00.00 by investigating nuclei at the limits of stability, nuclear astrophysics, the nature of neutrinos, and fundamental symmetry properties in nuclear systems. The coming decade in nuclear physics may reveal new nuclear phenomena and structure unlike anything known from the stable nuclei of the world around us. Nuclear physics research is essential if we are to solve important problems in astrophysics—the origin of the chemical elements, the behavior of neutron stars, the origin of the highest-energy cosmic rays, core-collapse supernovae and the associated neutrino physics, and galactic and extragalactic gamma-ray sources. Neutrinos are mysterious particles that permeate the universe and hardly interact with matter, yet play a key role in the explosion of stars. Recent experiments have shown that a neutrino oscillates among all of its three types as it travels from its source. This remarkable metamorphosis can only happen if neutrinos, long thought to have no mass at all, actually do have tiny masses. Measurements of nuclear structure and nuclear reactions are carried out primarily at the Argonne Tandem Linac Accelerator System (ATLAS) and the Holifield Radioactive Ion Beam Facility (HRIBF). Neutrino studies are primarily carried out with specialized detectors located deep underground or otherwise heavily shielded against background. Measurements of symmetry properties, particularly of the neutron, are carried out at the Los Alamos Neutron Science Center (LANSCE) and are being developed using the Spallation Neutron Source (SNS). The following indicators establish specific long-term goals in World-Class Scientific Research Capacity that the Nuclear Physics program is committed to, and progress can be measured against:

- investigating new regions of nuclear structure, studying interactions in nuclear matter like those occurring in neutron stars, and determining the reactions that created the nuclei of the chemical elements inside stars and supernovae; and
- determining the fundamental properties of neutrinos and fundamental symmetries by using neutrinos from the sun and nuclear reactors and by using radioactive decay measurements.

The Nuclear Theory subprogram will contribute to Program Goal 05.20.00.00 by providing the theoretical underpinning needed to support the interpretation of a wide range of data obtained from all the other Nuclear Physics subprograms, with the ultimate aim of advancing knowledge and providing insights into the most promising avenues for future research. An over-arching theme of this subprogram is an understanding of the mechanism of quark confinement and de-confinement—while it is qualitatively explained by Quantum ChromoDynamics (QCD), a quantitative description remains one of this subprogram’s great intellectual challenges. New theoretical tools will be developed to describe nuclear many-body phenomena, with important applications to condensed matter and other areas of physics. Understanding what consequences neutrino mass has for nuclear astrophysics and for the current theory of elementary particles and forces is also of prime importance. Computing resources that dwarf current capabilities are being developed to tackle challenging calculations of sub-atomic structure, such as those of lattice gauge QCD. The Nuclear Theory subprogram also supports an effort in nuclear data compilation and evaluation that serves a broad community of users much larger than the nuclear physics community.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 05.20.00.00 – Explore Nuclear Matter, from Quarks to the Starts					
Maintained and operated Nuclear Physics scientific user facilities so that the unscheduled operational downtime was 15%, on average, of total scheduled operating time. [Met Goal]	*Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 11%, on average, of total scheduled operating time. [Met Goal]*	*Maintained and operated Nuclear Physics scientific user facilities so the unscheduled operational downtime was 12%, on average, of total scheduled operating time. [Met Goal]*	*Maintained and operated Nuclear Physics scientific user facilities to the unscheduled operational downtime was 11% on average, of total scheduled operating time. [Met Goal]*	*Average achieved operation time of the scientific user facilities as a percentage of the total scheduled annual operation time will be greater than 80%.*	*Average achieved operation time of the scientific user facilities as a percentage of the total scheduled annual operation time will be greater than 80%.*
Met the cost and schedule milestones for construction of facilities and Major Items of Equipment within 10% of baseline estimates. Completed on schedule the Analysis System for Relativistic Heavy Ion Collider (RHIC) Detectors and RHIC Silicon Vertex Detector. [Met Goal]		Met the cost and schedule milestones for the construction of facilities and Major Items of Equipment within 10% of baseline estimates; completed on schedule the Solenoidal Tracker at RHIC (STAR) Electro-Magnetic Calorimeter (EMCAL). [Met Goal]			
Medium Energy Nuclear Physics					
As elements of the electron beam program, (a) completed fabrication of the BLAST detector at MIT/Bates in accordance with project milestones, and (b) conducted precise studies of nucleon structure, including studies of the proton's internal charge distribution and role of Quantum ChromoDynamics (QCD) in nuclear structure by delivering high intensity (140 micro amps), highly polarized (75%) electron beams with Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility (TJNAF). [Met Goal]	As elements of the electron beam program, (a) completed commissioning of the BLAST detector at MIT/Bates and initiated first measurements, and (b) completed fabrication, installation and commissioning of the G0 detector, a joint NSF-DOE project at TJNAF. [Mixed Results]	As elements of the electron beam program, (a) collected first data with the BLAST detector at MIT/Bates, studying the structure of nucleons and few body nuclei and (b) collected first data to map out the strange quark contribution to nucleon structure using the G0 detector, utilizing the high intensity polarized electron beam developed at TJNAF. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.4), Hall B (7.2), and Hall C (2.1), respectively, at the Continuous Electron Beam Accelerator Facility. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.9), Hall B (9.6), and Hall C (2.8), respectively, at the Continuous Electron Beam Accelerator Facility.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments in Hall A (2.1), Hall B (6.8), and Hall C (2.0), respectively, at the Continuous Electron Beam Accelerator Facility.
	Commissioned polarized protons at RHIC. [Met Goal]	Collected first data with polarized protons with the RHIC STAR, PHENIX and pp2pp detectors. [Met Goal]			

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Heavy Ion Nuclear Physics					
Produced first heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC – construction completed FY 1999) at 10% of its design luminosity, as planned, with four experimental detectors. Published first results of heavy-ion collisions. [Met Goal]	Completed first round of experiments at RHIC at full energy; achieved the full design luminosity (collision rate) of 2 x 10^{26} cm^{-2} s^{-1} for heavy ions. [Met Goal]	Initiated first round of experiments with collisions with other ions to compare to results of gold-gold collisions. [Met Goal]	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (900) and recorded by the STAR (40) detectors, respectively, at the Relativistic Heavy Ion Collider. [Met Goal]	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (1800) and recorded by the STAR (40) detectors, respectively, at the Relativistic Heavy Ion Collider.	Weighted average number (within 30% of baseline estimate) of millions of events sampled by the PHENIX (18,000) and recorded by the STAR (60) detectors, respectively, at the Relativistic Heavy Ion Collider.
Continued major accelerator improvement projects at RHIC in order to improve machine reliability and efficiency. [Met Goal]	Completed Helium Storage addition and liquid nitrogen standby cooling system at RHIC leading to better cost effectiveness ($0.5M savings) and operational efficiency (10% increase). [Mixed results]	Upgraded the RHIC cryogenics system by replacing turbine oil skids and removing seal gas compressor, eliminating a single point failure. [Met Goal]			
	Met the cost and schedule milestones for the PHENIX Muon Arm Instrumentation (Major Item of Equipment) within 10% of baseline estimates. [Met Goal]				
Low Energy Nuclear Physics					
			Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (25) and Holifield Radioactive Ion Beam (5.3) facilities, respectively. [Met Goal]	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (25) and Holifield Radioactive Ion Beam (3) facilities, respectively.	Weighted average number (within 20% of baseline estimate) of billions of events recorded by experiments at the Argonne Tandem Linac Accelerator System (21) and Holifield Radioactive Ion Beam (2.8) facilities, respectively.
Produced first results on the solar neutrino flux with the Sudbury Neutrino Observatory (SNO). SNO measures properties of solar neutrinos. [Met Goal]	Collected the first data from neutral current interactions from the Sudbury Neutrino Observatory (SNO). [Met Goal]	Collected the first data from the Kamioka Large Anti-Neutrino Detector (KamLAND), a joint U.S.-Japan experiment measuring neutrinos produced in nuclear reactors. [Met Goal]			

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Tested low-energy prototype of Rare Isotope Accelerator (RIA) fast catcher and tested low-beta accelerator cavities. [Met Goal]	Constructed a prototype high energy, high power gas catcher for the possible Rare Isotope Accelerator (RIA). [Met Goal]	Delivered the prototype high energy, high power gas catcher to the GSI facility in Germany and prepared it for testing. Completed tests of prototype targets for RIA. Complete prototype Electron Cyclotron Resonance ion source and fabricated prototypes of the high-beta superconducting radio frequency (RF) cavities for RIA. [Met Goal]			

Means and Strategies

The Nuclear Physics 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 Nuclear Physics program will support innovative, peer reviewed scientific research to advance knowledge and provide insights into the nature of energy and matter, in particular to investigate the fundamental forces that hold the nucleus of the atom together and determine the detailed structure and behavior of atomic nuclei. The program also builds and supports the forefront scientific facilities and instruments necessary to carry out that research. All research projects undergo regular peer review and merit evaluation based on procedures set down in 10 CFR 605 for the extramural grant program and under a similar process for laboratory programs and scientific user facilities. All new projects are selected through peer review and merit evaluation.

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

The Nuclear Physics program is closely coordinated with the research activities of the National Science Foundation (NSF). The major scientific facilities required by NSF supported scientists are usually the DOE facilities. NSF often jointly supports the fabrication of major research equipment at DOE user facilities. DOE and NSF jointly charter the Nuclear Science Advisory Committee (NSAC).

Scientists supported by the Nuclear Physics program collaborate with researchers from many countries. Large numbers of foreign scientists, who provide monetary and equipment support, heavily utilize all of the Nuclear Physics user facilities, especially RHIC at the Brookhaven National Laboratory (BNL) and CEBAF at TJNAF. The program also supports some collaborative work at foreign accelerator facilities. The program promotes the transfer of the results of its basic research to a broad set of technologies involving advanced materials, national defense, medicine, space science and exploration, and industrial processes. In particular, nuclear reaction data are an important resource for these programs. NP user facilities are utilized by other SC programs (e.g., High Energy Physics and Basic Energy Sciences), other DOE Offices (e.g., National Nuclear Security Administration and Nuclear Energy), other Federal agencies (e.g., National Science Foundation, National Aeronautics and Space Administration and Department of Defense) and industry to carry out their programs.

Validation and Verification

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

Program Assessment Rating Tool (PART)

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

Nuclear Physics (NP) program has incorporated feedback from OMB into the FY 2005 and FY 2006 Budget Requests and has taken the necessary steps to continue to improve performance.

In the PART review, OMB gave the NP program a high score of 85% overall which corresponds to a rating of "Effective." OMB found the program's management to be excellent with a relatively transparent budget justification and a fully engaged advisory committee that produces fiscally responsible advice. The assessment found that NP has developed a limited number of adequate performance measures which are continued for FY 2006. These measures have been incorporated into this Budget Request, NP grant solicitations, and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To better explain these complex scientific measures, SC has developed a website (http://www.sc.doe.gov/measures) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Nuclear Science Advisory Committee (NSAC) and also available on the website, will guide reviews, every five years by NSAC, of progress toward achieving the long term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report. In response to PART findings, NP 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. The COV report is available on the web (http://www.sc.doe.gov/henp/np/nsac/docs/COV_nsac_report_022604.pdf). NP developed and submitted an action plan to respond to the findings and recommendations of the COV. NSAC conducted an assessment and comparison of the capabilities of the Rare Isotope Accelerator (RIA) and the Gesellschaft für Schwerionenforschung (GSI) Future Facility in FY 2004. Their report is available on the web (http://www.sc.doe.gov/henp/np/nsac/docs/RIA-GSI-nsac-022604.pdf).

Funding by General and Program Goal

(dollars in thousands)

	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.20.00.00 Explore Nuclear Matter in All its Forms			
Medium Energy Nuclear Physics	118,854	124,831	111,660
Heavy Ion Nuclear Physics	161,451	174,550	161,879
Low Energy Nuclear Physics	71,053	75,982	68,537
Nuclear Theory	28,434	29,415	26,665
Construction	0	0	2,000
Total General Goal 5, World-Class Scientific Research Capacity	379,792	404,778	370,741

Overview

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

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

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

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

How We Work

The Nuclear Physics program uses a variety of mechanisms for conducting, coordinating, and funding nuclear physics research. The program is responsible for planning and prioritizing all aspects of supported research, conducting ongoing assessments to ensure a comprehensive and balanced portfolio, regularly seeking advice from stakeholders, supporting core university and national laboratory programs, and maintaining a strong infrastructure to support nuclear physics research. The R&D Investment Criteria's relevance principles encourage research community investments in making program priorities. The Nuclear Science Advisory Committee (NSAC) and Program Advisory Committees (PACs) at our facilities have served the program well in this respect. Quality and performance are assured by peer-review of research projects and facility operations. The performance data obtained in facility and program reviews, as well as Annual Performance Results and Targets are used in assuring quality and in making funding decisions.

Advisory and Consultative Activities

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

The **Nuclear Science Advisory Committee** (NSAC) provides advice to the DOE and the National Science Foundation on a continuing basis regarding the direction and management of the national basic nuclear sciences research program. In FY 2004, the DOE Nuclear Physics program provided about 90% of the federal support for fundamental nuclear physics research in the nation. The National Science Foundation (NSF) provided most of the remaining support. NSAC regularly conducts reviews that evaluate the scientific productivity and opportunities of major components of the Office's research program and proposed major new initiatives and provide advice regarding scientific priorities. One of the most important functions of NSAC is development of long-range plans that express community-wide priorities for the upcoming decade of nuclear physics research.

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

Facility Operations Reviews

In FY 2002 the Nuclear Physics program conducted operations reviews of its two largest national user facilities: the Relativistic Heavy Ion Collider (RHIC) and Continuous Electron Beam Accelerator Facility (CEBAF). Conducted by SC's Construction Management Support Division, these reviews enlisted experts from DOE national laboratories and NSF-supported university nuclear physics facilities to evaluate present performance and costs of operations. The Office of Nuclear Physics conducted operations reviews of the Holifield Radioactive Ion Beam Facility (HRIBF) in FY 2003 and the Argonne Tandem Linac Accelerator System (ATLAS) facility in FY 2004, using such external experts. Annual reviews of the RHIC, CEBAF, ATLAS and HRIBF programs with external reviewers are also conducted to assess the performance and scientific productivity of the facilities.

Program Reviews

NSAC, on a rotating schedule, reviews the major elements of the nuclear physics program. These reviews examine scientific progress in each program element against the previous long-range plan, assess the scientific opportunities, and recommend reordering of priorities based upon existing budget profiles. The Medium Energy subprogram was reviewed in 1998, the Low Energy subprogram in 2001, and the Theory subprogram in 2003. A review of the Heavy Ion subprogram was completed in 2004. Quality and productivity of university grants are peer reviewed on an approximately three-year basis and laboratory groups performing research will be peer reviewed on an approximately four-year basis. The first review of laboratory research groups occurred for the Heavy Ion subprogram in January, 2004.

Planning and Priority Setting

The strategic plan for NP is set forth in the recently completed DOE and SC Strategic Plans. The objectives in this plan have been developed with the assistance of NSAC. Indeed, one of the most important activities of NSAC is the development of long-range plans that serve as a framework for the coordinated advancement of the field for the coming decade. These plans are undertaken every five to six years to review the scientific opportunities in the field, perform retrospective assessments of the major accomplishments by the field, and set priorities for the future. NSAC recommended as its highest priority the effective utilization of its existing facilities, especially the recently completed facilities, to extract the science for which they were built. This includes adequate support for facility operations and for university and laboratory research efforts. Priority was also given to making investments for capabilities needed to mount a forefront program in the future. Guidance from the NSAC long range plan has been augmented by NSAC reviews of subfields. Priority within the recent budgets has been given to implementing these recommendations made in the NSAC reviews of the Medium Energy and Low Energy subprograms by making tough programmatic decisions. In FY 2004, the 88-Inch Cyclotron at Lawrence Berkeley National Laboratory ceased to operate as a national nuclear physics user facility and transitioned to a facility supported jointly by the National Reconnaissance Office (NRO) and the Air Force (USAF) for testing electronic components and by NP for a small in-house research program. In FY 2005, operations of the MIT/Bates Linear Accelerator Center will be terminated with completion of the research program using the Bates Large Acceptance Spectrometer Toroid (BLAST) detector. NSAC recommendations on scientific opportunities and priorities, provided in recent reviews of neutron science and the Nuclear Theory and Heavy Ion subprograms, are reflected in the programmatic decisions in FY 2005 and FY 2006 budget requests. These decisions have been made to maximize the scientific impact, productivity, quality and cost-effectiveness of the program with the resources available. The NSAC Long Range Plan identified the proposed Rare Isotope Accelerator (RIA) as the highest priority for major new construction. RIA was identified as a near-term priority in SC future facilities plan, Facilities for the Future of Science: A Twenty-Year Outlook. Furthermore, the NSAC Long-Range Plan recommended an upgrade of CEBAF from 6 to 12 GeV; this project was also identified as a near-term priority in SC facilities plan. In an era of constrained budgets the Nuclear Physics program needs to develop a strategic plan for implementing its vision for the future. Guidance will be sought from NSAC regarding opportunities and priorities for the Nuclear Physics program in the context of fiscal constraints. NP participated in the Interagency Working Group (IWG) that developed the National Science and Technology Council (NSTC) Report: A 21st Century Frontier for Discovery: The Physics of the Universe. A Strategic Plan for Federal Research at the Intersection of Physics and Astronomy. NP is playing a leading role in two of the major scientific thrusts identified in this report: Origin of Heavy Elements and High Energy Density Physics. Funding is provided in FY 2006 to support these initiatives.

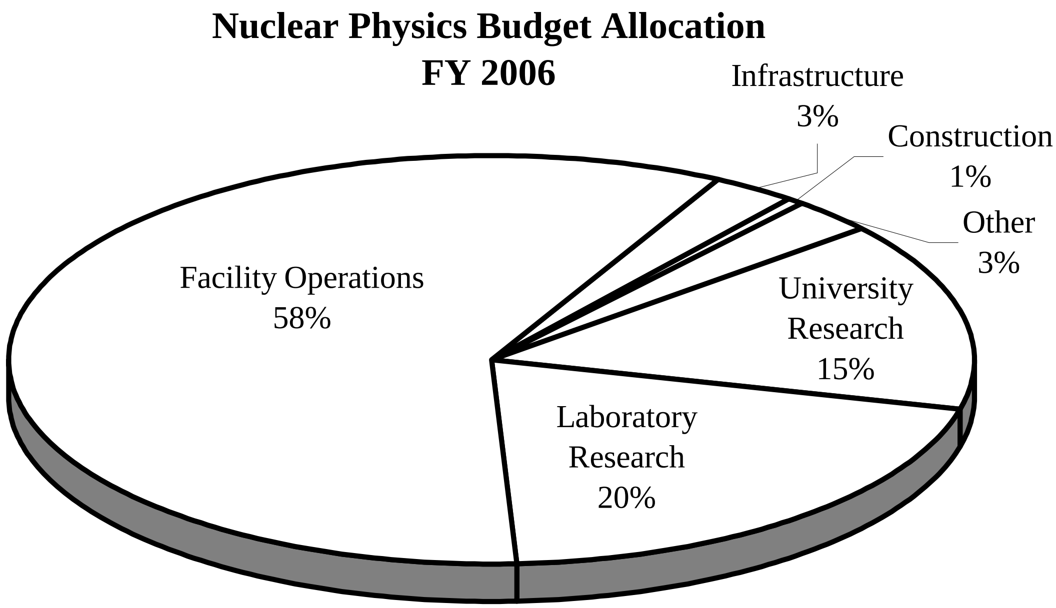
Committee of Visitors

A Committee of Visitors was appointed by the Nuclear Science Advisory Committee to review the management practices of the Nuclear Physics program and made its visit in December, 2003. In particular they examined the decision process for awarding grants and for determining priorities of funding among the various activities within the Nuclear Physics program. The Committee found that the Nuclear Physics program “carries out its duties in an exemplary manner,” but suggests “a number of minor operational changes which may benefit the program managers and reviewers in carrying out their tasks more efficiently.”

How We Spend Our Budget

The FY 2006 budget request is focused on optimizing, within the resources available, the scientific productivity of the program by ensuring a proper balance of research scientists and technicians, facility operations, and investments in needed tools and capabilities. Approximately 35% of the funding is provided for research personnel to utilize the program’s user facilities, complete important experiments and to fabricate experimental instrumentation. Approximately 58% of the funding is provided for operations of the program user facilities, for support of NP’s share of the in-house program at the 88-Inch Cyclotron and to carry out decontamination and decommissioning (D&D) activities at the

MIT/Bates facility. Approximately 4% is provided for infrastructure and for construction projects that are needed to extract the science and improve efficiencies in the outyears at RHIC and TJNAF and 3% for other activities that includes Small Business Innovative Research (SBIR) and Small Business Technology Transfer (STTR) programs.



Research

Over one-third of the program's funding is provided to scientists at universities and laboratories to conceive and carry out the research. The DOE Nuclear Physics program involves over 1900 researchers and students at over 100 U.S. academic, federal and private sector institutions. The program funds research activities at over 85 academic institutions located in 35 states and at 7 DOE Laboratories in 6 states. Funding for university and national laboratory research (excluding capital equipment, proposed RIA R&D, and Lattice QCD computing investments) is decreased ~6.5% compared to FY 2005, resulting in ~9% decrease in personnel. National laboratory research scientists work together with the experimental collaborations to collect and analyze data as well as support and maintain the detectors. The laboratories provide state-of-the-art resources for detector and accelerator R&D for future upgrades and new facilities. The division of support between national laboratories and universities is adjusted to maximize scientific productivity.

- ***University Research***: University researchers play a critical role in the nation's research effort and in the training of graduate students. In FY 2004 the DOE Nuclear Physics program supported approximately two-thirds of the nation's university researchers and graduate students doing fundamental nuclear physics research. Among the 85 academic institutions, DOE supports researchers in 5 university laboratories with local accelerators (Texas A&M Cyclotron Laboratory, Triangle Universities Nuclear Laboratory (TUNL) at Duke University, MIT Laboratory for Nuclear Science, University of Washington, and Yale University). DOE also supports the Institute for Nuclear Theory at the University of Washington. In recent years about 80 Ph.D. degrees have been granted annually to students for research supported by the program. One-half of those who received nuclear science Ph.D.'s between 1980 and 1994 are pursuing careers outside universities or national laboratories in such diverse areas as nuclear medicine, medical physics, space exploration, and national security.

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

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

The Nuclear Physics program funds field work proposals from the national laboratories. Performance of the laboratory groups is reviewed every year to examine the quality of their research and identify needed changes, corrective actions or redirection of effort. Individual laboratory groups have special capabilities or access to laboratory resources that can be profitably utilized in the development of the scientific program.

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

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

Significant Program Shifts

In the FY 2006 budget request the scientific scope of the nation’s nuclear physics program is maintained. In the context of an overall 8.4% reduction in funding, priority has been given to maintaining a productive program focused on attaining the scientific goals of the program. This requires a balance in on-going facility operations and research support and investments in capabilities needed to successfully attain these goals. Funding required for MIT/Bates in FY 2006 decreases with its termination of operations in FY 2005. In keeping with PART findings and principles, this will allow resources for the remaining user facilities (BNL/RHIC, TJNAF/CEBAF, ANL/ATLAS, and ORNL/HRIBF) with operations at these facilities at 65% of optimum utilization. The investments in these facilities are allocated to optimize their scientific programs. FY 2006 investments in capital equipment addresses opportunities identified in the 2002 NSAC Long Range Plan and in subsequent NSAC recommendations. At RHIC, funding is provided for needed detector upgrades by redirecting funds available for operations of the facility and existing detectors. At TJNAF, funding is provided for 12 GeV CEBAF Upgrade R&D and conceptual design activities. These investments in capabilities are critical for the scientific viability of the facilities and their program in the outyears. At ATLAS and HRIBF, the priority is on minimizing the impacts of the reductions on the facility operations. In the Memorandum of Understanding for the 88-Inch Cyclotron developed for FY 2004-2005, NRO and USAF provide $2,000,000 for 2,000 hours for their tests and NP provides $3,000,000 for a 3,000 hour in-house nuclear physics program. Following evaluations in the summer of 2004 by NRO, USAF, and NP, it was determined that a continued need for 88-Inch Cyclotron beams exists and a Memorandum of Agreement (MOA) for the continuation of this arrangement for FY 2006-2011 is being developed for signature. In FY 2006, NP funding is requested to support 88-Inch operations for an in-house nuclear physics program consistent with the NRO/USAF/DOE MOA. The research programs at the major user facilities are integrated partnerships between DOE scientific laboratories and the university community, and the planned experimental research activities are considered essential for scientific productivity of the facilities. Funding for university and national laboratory researchers and graduate students decreases 6.8% compared to the FY 2005 appropriation. R&D activities for the proposed RIA are maintained at the FY 2005 Congressional budget request level.

Scientific Discovery through Advanced Computing

The Scientific Discovery through Advanced Computing (SciDAC) activity is a set of coordinated investments across all SC mission areas with the goal to achieve breakthrough scientific advances through computer simulation that were impossible using theoretical or laboratory studies alone. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists and mathematicians.

The Nuclear Physics program funds SciDAC programs in the areas of theoretical physics (National Computational Infrastructure for Lattice Gauge Theory), astrophysics (Shedding New Light on Exploding Stars: TeraScale Simulations of Neutrino-Driven Supernovae and their Nucleosynthesis), and grid technology (Particle Physics Data Grid Collaborative Pilot) that support the scientific goals of the Nuclear Physics subprograms. The principal goal of the Tera Scale Supernova simulations is to understand the mechanism responsible for the explosions of massive stars–arguably, the dominant source of most elements in the Periodic Table between oxygen and iron. The National Computational Infrastructure for Lattice Gauge Theory has as an aim to make precision numerical calculations of Quantum ChromoDynamics (QCD) in order to determine the structure and interactions of hadrons and the properties of nuclear matter under extreme conditions. This activity provides results complementary to a similar activity by the High Energy Physics program. The Particle Data Grid project has allowed Nuclear Physics experiments to tackle the task of replicating thousands of files at high speeds with rates in excess of 3-4 terabyte/week.

Lattice Quantum ChromoDynamics Computing

Quantum ChromoDynamics (QCD) is a very successful theory that describes the fundamental strong interactions between quarks and gluons. The lack of precision in current QCD calculations is now limiting the understanding of many experimental results in high-energy and nuclear physics, including many measurements at the Stanford Linear Accelerator Center (SLAC) B-Factory, the Fermilab Tevatron, the Brookhaven Relativistic Heavy Ion Collider (RHIC) and the Thomas Jefferson National

Accelerator Facility (TJNAF). Recent advances in numerical algorithms coupled with the ever-increasing performance of computing have now made a wide variety of QCD calculations feasible, though most calculations of interest still require very significant computing resources (~10^{12-14} computational operations or 1-100 Teraflops).

An effort with the High Energy Physics (HEP) and Advanced Scientific Computing Research (ASCR) programs is aimed towards the development of a ~5 Teraflops prototype computer by the end of 2005, using the custom QCD On-a-Chip (QCDOC) technology. This platform will enable U.S. researchers to stay competitive with other worldwide efforts in computational QCD research while developing a larger-scale hardware platform. In a joint effort with HEP, development of large-scale facilities (~20 Teraflops) will begin in FY 2006 for providing computing capabilities based on the most promising technology. This effort will be captured in a single Major IT investment.

Scientific Facilities Utilization

The Nuclear Physics request for FY 2006 supports the Department's scientific user facilities. In FY 2004 Nuclear Physics operated five national user facilities, which provided research time for scientists in universities and other Federal laboratories. In FY 2005, the program supports operations at:

- The Relativistic Heavy Ion Collider (RHIC) complex at Brookhaven National Laboratory;
- The Continuous Electron Beam Accelerator Facility (CEBAF) at Thomas Jefferson National Accelerator Facility;
- The Bates Linear Accelerator Center at Massachusetts Institute of Technology;
- The Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL); and
- The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL).

These facilities provide beams for research for a user community of about 2,240 scientists. The FY 2006 Budget Request will support operations of four facilities (operation of MIT/Bates is terminated in FY 2005) that will provide ~14,695 hours of beams for research, a ~32% decrease from the anticipated beam hours in FY 2005 that includes MIT/Bates operations. (The operating facilities will overall operate ~21% less than in FY 2005.)

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

	FY 2004	FY 2005	FY 2006 Request
Number of Facilities	5	5	4
Optimal Hours	27,675	25,800	22,675
Planned Operating Hours	21,265	21,660	14,695
Achieved Operating Hours	24,280	–	–
Unscheduled Downtime – Major user facilities	11%	–	–
Number of Users[a]	2,290	2,240	2,100

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.

Origin of Heavy Elements

While we have a relatively good understanding of the origin of the chemical elements in the cosmos lighter than iron, the production of the elements from iron to uranium remains a puzzle. A sequence of rapid neutron capture by nuclei known as the r-process (where r is for rapid), is clearly involved, as may be seen from the observed abundances of the various elements. Supernovae explosions, neutron-star mergers, or gamma ray bursters are possible locales for this process. Tremendous forces must fuse lighter elements into the heavier ones, but our incomplete understanding of these events leaves the question open. The approach to understanding the origin and role of the heavy elements in the cosmos involves advances on several fronts including astrophysical observations of nucleosynthesis signatures in all spectral regions, studies of the abundances of elements in stars and supernovae, large-scale computer simulations for better theoretical interpretation of nuclear processes, and measurement of properties of exotic nuclei.

NP supports this scientific initiative with studies of exotic nuclei and reactions at its existing facilities and by development of plans for the proposed Rare Isotope Accelerator (RIA) that will enable study of exotic nuclei at the very limits of stability and make almost all the relevant r-process nuclei accessible for study. DOE has approved mission need (CD-0) for RIA. Funding is provided in FY 2006 for R&D.

High Energy Density Physics

When the Universe was a billionth of a second old, nuclear matter is believed to have existed in its most extreme energy density form called the quark-gluon plasma. Experiments at RHIC are underway to find and characterize this state of matter. In the future, a luminosity upgrade at RHIC would permit measurements of the earliest highest energy-density stage in the formation and development of the quark-gluon plasma, the study of which is facilitated by measurements with rare-particle probes.

The High Energy Density Physics activities include the support of the operation of RHIC and the accompanying research program at universities and laboratories. Research and development activities, including the development of an innovative electron beam cooling system at RHIC, are expected to demonstrate the feasibility of increasing the luminosity or collision rate of the circulating beams by a factor of 10. Such an increase will allow measurements of the production rate of the J/ψ and other

[a] Due to multiple facilities some users may be multiply counted.

"charmonium" mesons that are believed to be a key indicator of possible new phenomena. With very large data samples, more precise studies will become possible of particles emanating from the hot, dense matter during its very brief existence. This will allow a detailed tomography of the hot matter as it evolves.

Construction and Infrastructure

In FY 2006, funding for capital equipment is increased by 0.7% and for accelerator improvement projects is decreased by 37% (after $2,000,000 is redirected to initiate the Electron Beam Ion Source (EBIS) project) compared to FY 2005. Project Engineering and Design (PED) funding is provided in FY 2006 for the EBIS at BNL that will replace the aging Tandem Van de Graaff accelerator as the injector for RHIC. The Nuclear Physics program, as part of its responsibilities as the landlord for BNL and TJNAF, will provide funding for general plant projects (GPP) to both sites and general purpose equipment (GPE) to BNL only. Funding for GPP is increased by 2.9% in FY 2006 compared to FY 2005.

Workforce Development

The Nuclear Physics program supports development of the Research and Development (R&D) workforce through support of undergraduate researchers, graduate students working toward a doctoral degree, and postdoctoral associates developing their research and management skills. The R&D workforce developed under this program provides new scientific talent in areas of fundamental research. It also provides talent for a wide variety of technical, medical, security and industrial areas that require the finely-honed thinking and problem-solving abilities and the computing and technical skills developed through an education and experience in a fundamental research field. Scientists trained as Nuclear Physicists can be found in such diverse areas as nuclear medicine, medical physics, space exploration, and national security. The Outstanding Junior Investigator (OJI) program, initiated in FY 2000, through ~4 new awards each year, has been very successful in identifying, recognizing, and supporting promising young faculty.

About 875 postdoctoral research associates and graduate students supported by the Nuclear Physics program in FY 2004 were involved in a large variety of experimental and theoretical research projects. Over one fifth of these researchers are involved in theoretical research. Those involved in experimental research utilize a number of scientific facilities supported by the DOE, NSF, and foreign countries. The majority of the experimental postdoctoral associates and graduate students (~80%) conducted their research at the Nuclear Physics user facilities.

Details of the DOE Nuclear Physics manpower are given below. In FY 2004 there were about 270 faculty researchers supported at the universities (~1.4 per grant), with an average award of ~$220,000 per faculty researcher. Almost all grants are awarded with project periods of three years.

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	190	185	175
Average size (excluding CE)	$309,000	$327,000	$312,000
# Laboratory Groups	28	28	27
# Permanent Ph.D.'s (manpower count)	746	745	690
# Postdoctoral Associates (manpower count)	403	400	340
# Graduate Students (manpower count)	473	470	420
# Ph.D.'s awarded	66	66	60

Medium Energy Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Medium Energy Nuclear Physics					
Research					
University Research	15,179	15,542	14,751	-791	-5.1%
National Laboratory Research	15,288	15,411	15,015	-396	-2.6%
Other Research	350	5,477	5,053	-424	-7.7%
Total, Research	30,817	36,430	34,819	-1,611	-4.4%
Operations					
TJNAF Operations	75,543	78,996	72,341	-6,655	-8.4%
Bates Operations	12,494	9,405	4,500	-4,905	-52.2%
Total, Operations	88,037	88,401	76,841	-11,560	-13.1%
Total, Medium Energy Nuclear Physics	118,854	124,831	111,660	-13,171	-10.6%

Description

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

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

Benefits

The Medium Energy subprogram seeks to advance our knowledge of the internal structure of protons and neutrons, the basic constituents of all nuclear matter, by providing precision experimental information concerning the quarks and gluons that form the protons and neutrons. This program, in coordination with the Theory subprogram, seeks to provide a quantitative description of these particles in terms of the fundamental theory of the strong interaction, Quantum ChromoDynamics. This work provides a basis for our description of matter in terms of its fundamental constituents and strengthens scientists' ability to explore how matter will behave under conditions that cannot be duplicated by man. To accomplish this task, the Medium Energy subprogram operates the Thomas Jefferson National Accelerator Facility (TJNAF), supports research at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory, and supports university researchers to carry out the experiments at these facilities. These research activities contribute to the training of the next generation of scientists and engineers that will contribute to the Department's nuclear and energy missions.

Supporting Information

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

(1) determining the distribution of up, down, and strange quarks in the nucleons,
(2) determining dynamic degrees of freedom of the quarks by measuring the excited states of hadrons (any composite particle made of quarks, such as nucleons),
(3) measuring the effects of the quark and gluon polarizations within the nucleon,
(4) determining the role of the “sea” of virtual quarks and gluons, which also contributes to the properties of protons and neutrons, and
(5) measuring the properties of simple, few-nucleon systems, with the aim to describe them in terms of their fundamental components.

Most of this work is done at this subprogram’s primary research facility, TJNAF, but the program also has a major research effort at RHIC. Individual experiments are supported at the National Synchrotron Light Source at Brookhaven, the High Intensity Gamma Source (HIGS) at Triangle University Nuclear Laboratory, Fermilab, and at several facilities in Europe. All these facilities produce beams of sufficient energy (small enough wavelength) to probe at a scale within the size of a nucleon.

The operation of the national user facility, TJNAF, serves yearly a nationwide community of about 300 DOE and about 300 National Science Foundation (NSF) supported scientists and students from over 140 U.S. institutions and about 300 scientists from 19 foreign countries. Many of these scientists are from the European Center for Nuclear Research (CERN) member states. At TJNAF, the NSF has made a major contribution to new experimental apparatus in support of the large number of NSF users. Foreign collaborators have also made a significant investment in experimental equipment. Allocation of beam time at TJNAF is based on guidance from Program Advisory Committees that review and evaluate proposed experiments regarding their merit and scientific priority.

FY 2004 Accomplishments

Scientists supported by this subprogram have made important discoveries in the past decade. The assembly of a large set of precision nucleon-nucleon scattering data, for example, has provided critical input for theoretical models that now produce a significantly more quantitative description of nuclei, making possible the development of a “Standard Model for Nuclei.” The past decade has seen a growing interest by the field to understand nucleons in terms of the quarks and gluons of QCD. Advances in both theory and experiment have spurred this interest. The NSAC Long-Range Plan singled out three significant achievements of the Medium Energy subprogram related to the important central question of the structure of the nucleon:

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

Recent developments include:

- Continuing the search for five-quark states: Data collection for a new search for a five-quark (pentaquark) state called the θ^+ (theta-plus) with over an order of magnitude more sensitivity has just been completed at TJNAF.
- Connecting individual and coherent quark-gluon behavior in the nucleon: A major question in understanding the behavior of the quarks and gluons (partons) that are tightly bound inside the proton is how the individual behavior of the partons relates to their coherent behavior through the response of the proton as a whole to external probes. New data from TJNAF indicate that a relatively simple relationship previously seen in specific situations appears to hold universally. This result was somewhat surprising in that scientists expected the relationship to be much more complicated.
- First direct evidence for nucleon-nucleon correlations inside light nuclei: Data on the breakup of helium-3 nuclei (two protons and one neutron) by electrons from the CEBAF Large Acceptance Spectrometer (CLAS) detector at TJNAF have, for the first time, demonstrated a strong correlation between the velocities of the neutron and one of the protons emitted in the breakup. This correlation information is important for the ab-initio calculations of light nuclei.
- The MiniBooNE experiment is proceeding on schedule: This experiment started collecting data in October 2002 and has collected 50% of the expected minimum number of neutrino events needed for a statistically significant measurement of neutrino oscillations. These data are important for determining whether or not sterile (non-interacting) neutrinos exist.

FY 2004 Facility and Technical Accomplishments:

- The BLAST Detector at the MIT/Bates facility has produced preliminary results: The Bates Large Acceptance Spectrometer Toroid (BLAST) has produced preliminary results on precision measurements of the electromagnetic form factors for the proton and neutron as well as a precision determination of the spin structure of the deuteron.
- Development of a new "frozen-spin" polarized target: The Laser Electron Gamma Source (LEGS) experiment at BNL has successfully commissioned a revolutionary new polarized frozen hydrogen-deuterium target that will make possible the highest quality measurements ever made of the spin structure of the proton and neutron at energies near the threshold for excitation of these nucleons.
- Atom Trapping Trace Analysis finds new uses: A novel technique using lasers has been developed that allows scientists to identify and count individual atoms of the rare isotopes at sensitivities of one atom per billion of the naturally occurring abundance. This technique has been successfully used to date ground water in an ancient Egyptian aquifer to determine the flow of water in the aquifer and in medical research for measuring bone density in human subjects.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research	**30,817**	**36,430**	**34,819**
▪ **University Research**	**15,179**	**15,542**	**14,751**

These activities comprise a broad program of research, and include support of about 150 scientists and 95 graduate students at 32 universities in 17 states and the District of Columbia. These research efforts utilize not only each of the accelerator facilities supported under the Medium Energy subprogram, but also other U.S. and foreign accelerator laboratories. Support for university research decreases by 5.1%, resulting in a ~9% reduction in existing Ph.D. researchers and graduate students supported.

• **Bates Research**	**2,400**	**2,500**	**2,152**

MIT scientists along with other university researchers used the BLAST to make measurements in FY 2004 and FY 2005 to obtain information about the structure of the nucleon and the nature of the nucleon-nucleon force. In FY 2006 support is provided to complete data analysis.

• **Other University Research**	**12,779**	**13,042**	**12,599**

Most of the university research activities are associated with the main facilities at TJNAF and RHIC. At TJNAF the experiments are largely focused on the study of nucleon structure and its internal dynamics. Hall A experiments are expected to make a sensitive measurement of the radial extent of the neutron distribution in the lead-206 nucleus. Hall B experiments are expected to perform a pentaquark search and to make a precision measurement of the half life of the neutral pion. Hall C expects to complete the G0 experiment which will determine the strange quark contribution to the proton electromagnetic structure.

A number of university groups are collaborating in experiments using the BLAST detector at the MIT/Bates Linear Accelerator Center that are completed in FY 2005. Support is provided for data analysis from BLAST precision polarization measurements of the proton and nuclear structure measurements on light nuclei.

University scientists and national laboratory collaborators will continue to develop the RHIC Spin program at Brookhaven National Laboratory. This program is expected to provide critical information on the contribution of gluons to the nucleon’s intrinsic spin. Complementary research efforts that will have reduced support in FY 2006 include: the HERMES (HERa MEasurements with Spin) experiment at the DESY laboratory in Hamburg, Germany; the Crystal Ball detector at the MAMI (MAinzer MIkrotron) electron accelerator in Mainz, Germany; and the precision experiments in weak decay at the Paul Scherrer Institute, Switzerland.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**15,288**	**15,411**	**15,015**

Included are: (1) the research supported at the TJNAF, that houses the world's most powerful high intensity continuous wave electron accelerator and (2) research efforts at Argonne, Brookhaven, and Los Alamos National Laboratories. The national laboratory groups carry out research at various world facilities as well as at their home institutions.

• **TJNAF Research**	**5,187**	**5,236**	**5,057**

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 experimental support and operate the detectors for safe and effective utilization by the user community. TJNAF scientists participate in the laboratory's research program. Support is reduced by 3.4% compared to FY 2005, resulting in scientific and technical staff reductions.

• **Other National Laboratory Research**	**10,101**	**10,175**	**9,958**

Support for research activities at accelerator and non-accelerator facilities at national laboratories is reduced by 2.1% compared to FY 2005. Resources are directed towards the highest priority activities that include support for efforts at TJNAF and RHIC, and completion of the LEGS experiment at BNL. The activities supported are described below:

- ► Argonne National Laboratory scientists will pursue research programs at TJNAF. The theme running through this entire effort is the search for a detailed understanding of the internal quark-gluon structure of the nucleon. ANL scientists have also made important advances in a new laser atom-trapping technique, Atom Trap Trace Analysis (ATTA), that will be used in measurements of rare isotopes for precision studies of nuclear structure.
- ► At Brookhaven National Laboratory, the Medium Energy Research group will continue to play a leading role in the RHIC-Spin research program. This is the set of experiments at RHIC that use colliding polarized proton beams to investigate the spin content of the nucleon and, in particular, the role of gluons.
- ► Also at Brookhaven, Laser Electron Gamma Source (LEGS) scientists are operating a new spectrometer and a recently developed polarized frozen hydrogen-deuterium target for a program of spin physics at low energies to measure the structure of the nucleon. This unique facility produces polarized gamma-rays by back scattering laser light from the circulating electron beam at the National Synchrotron Light Source.
- ► At Los Alamos National Laboratory, scientists and collaborators are participating in a next-generation neutrino oscillation experiment that builds on the experience of the Liquid Scintillator Neutrino Detector (LSND) experiment at Los Alamos, which detected a signal consistent with the existence of neutrino oscillations. The Mini Booster Neutrino Experiment (MiniBooNE) uses neutrinos generated from the Fermi National Accelerator Laboratory Booster proton beam; data collection began in FY 2002. Approximately half of the minimum expected required amount of data for a statistically significant measurement had been collected as of May 2004. Preliminary results are expected at the end of FY 2005.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- ► Los Alamos scientists also are involved in experiments at RHIC (RHIC Spin) that will probe the gluonic contribution to the spin of the proton. The Los Alamos group has also been instrumental in providing major components of the PHENIX detector at RHIC that are crucial in carrying out the RHIC Spin program of research.

The FY 2006 Request will provide resources to complete the LEGS experiment at BNL, and efforts at TJNAF and RHIC will be continued but with reductions in productivity because of staff reductions. Other activities are phased out as measurements are completed.

▪ **Other Research**	**350**	**5,477**	**5,053**

In FY 2004, $3,807,000 was transferred to the SBIR program and $1,053,000 was transferred to the STTR program. This activity includes $3,771,000 for SBIR and $1,096,000 for STTR in FY 2005 and $3,414,000 for SBIR and $996,000 for STTR in FY 2006 and other established obligations that the Medium Energy Nuclear Physics subprogram must meet.

Operations	**88,037**	**88,401**	**76,841**
▪ **TJNAF Operations**	**75,543**	**78,996**	**72,341**

Included is the funding that supports: (1) operation of the Continuous Electron Beam Accelerator Facility (CEBAF) at TJNAF, and (2) major human resources, equipment, and staging support for the assembly and dismantling of complex experiments.

• **TJNAF Accelerator Operations**	**48,592**	**52,276**	**47,161**

Accelerator operations in FY 2006 support a 3,545 hour running schedule; a decrease of ~29% in operating hours compared to FY 2005 that corresponds to ~66% utilization of the facility. At this level of funding the accelerator provides beams of differing energies and currents simultaneously to all three experimental halls. Recent investments in AIP projects have improved the reliability of CEBAF resulting in a decrease in unscheduled downtime from 17.8% in FY 2002 to 11.6% in FY 2004, a significant improvement. Support in FY 2006 is directed at continuing necessary accelerator improvement projects (AIP) and infrastructure improvements at a reduced level compared to FY 2005. Efforts in developing advances in superconducting radiofrequency technology are slowed down and focused on the highest priority new capabilities for SC missions.

	FY 2004	FY 2005	FY 2006
TJNAF Hours of Operation with Beam	5,238	4,985	3,545

Funding of $1,500,000 is provided for R&D and conceptual design activities for the upgrade of CEBAF to 12 GeV. The upgrade is recommended as one of the highest priorities for Nuclear Physics in the 2002 NSAC Long Range Plan for Nuclear Science, was identified as a near-term priority in the SC 20-Year Facilities Plan, and received Mission Need (CD-0) approval by the Department in March 2004.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
• **TJNAF Experimental Support**	**26,951**	**26,720**	**25,180**

These funds provide 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. In FY 2006, funding for experimental support is decreased by 5.8% compared to FY 2005.

Capital equipment funds ($5,706,000) are used towards assembly and installation of ancillary equipment items such as polarized targets for experimental Halls A, B, and C; spectrometer systems; the completion of a major upgrade of the data reduction system to handle massive amounts of raw data; and the continuation of the fabrication of second generation experiments. The Q-weak detector system is being developed to perform a precision measurement of the weak charge of the proton.

▪ **Bates Operations**	**12,494**	**9,405**	**4,500**

MIT/Bates Linear Accelerator Center is provided funding for phase-out and decontamination and decommissioning (D&D) activities.

	FY 2004	FY 2005	FY 2006
Bates Hours of Operation with Beam	5,177	3,125	0

Operations of the MIT/Bates Linear Accelerator Center will be phased out in FY 2005, and D&D activities will be started in FY 2005. Discussions are underway with MIT regarding disposal of property and the final state of the site. Costs of D&D range up to ~$16,000,000 for decontamination of all buildings and removal of their contents. Costs may decrease depending on the final disposition plan and whether ownership of the buildings and some of the equipment are transferred to MIT.

Total, Medium Energy Nuclear Physics	**118,854**	**124,831**	**111,660**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)

Research

▪ **University Research**

Funding supports the continuation of the MIT/Bates research effort focused on analysis of BLAST data. Phase out of support for Bates research staff continues in FY 2006	-348

	FY 2006 vs. FY 2005 ($000)
The research support at other universities decreases by 3.4% relative to FY 2005 and is focused on those university programs that support TJNAF and RHIC Spin-physics research programs.	-443
Total, University Research	**-791**
▪ **National Laboratory Research**	
Funding for capital equipment decreases by $77,000 from FY 2005. Funding for research support decreases ($319,000) reducing support to efforts in RHIC Spin and MiniBooNE.	-396
▪ **Other Research**	
Estimated SBIR/STTR and other obligations decrease.	-424
Total, Research	**-1,611**
Operations	
▪ **TJNAF Operations**	
TJNAF Accelerator Operations: Accelerator operating funds are decreased by 7.4% ($3,736,000) and support for accelerator science R&D for superconducting radiofrequency technology is reduced ($-1,250,000) relative to FY 2005. This funding supports a 3,545 hour running schedule (66% of optimum utilization) and R&D and conceptual design activities for a possible 12 GeV upgrade. Included is funding for AIP/GPP ($1,871,000) that is decreased by $129,000 compared to FY 2005.	-5,115
TJNAF Experimental Support: The decrease of 5.6% ($-1,146,000) for Experimental Support relative to FY 2005 supports the reduced running schedule. Capital equipment funding ($5,706,000) is reduced $394,000 compared to FY 2005.	-1,540
Total, TJNAF Operations	**-6,655**
▪ **Bates Operations**	
With the termination of operations, the funding for Bates is decreased from FY 2005. Funds are provided for decontamination and decommissioning (D&D) activities.	-4,905
Total, Operations	**-11,560**
Total Funding Change, Medium Energy Nuclear Physics	**-13,171**

Heavy Ion Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Heavy Ion Nuclear Physics					
Research					
University Research	12,392	12,720	12,113	-607	-4.8%
National Laboratory Research	17,984	16,673	17,546	+873	+5.2%
Other Research	0	3,917	3,609	-308	-7.9%
Total, Research	30,376	33,310	33,268	-42	-0.1%
Operations					
RHIC Operations	120,547	130,473	117,868	-12,605	-9.7%
Other Operations	10,528	10,767	10,743	-24	-0.2%
Total, Operations	131,075	141,240	128,611	-12,629	-8.9%
Total, Heavy Ion Nuclear Physics	161,451	174,550	161,879	-12,671	-7.3%

Description

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

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

Benefits

The Heavy Ion Nuclear Physics subprogram supports all elements of the Nuclear Physics mission by engaging in fundamental experimental research directed at acquiring new knowledge on the novel properties and the phases of hot, high energy density nuclear matter such as existed in the early universe; by developing and operating the world-class facility, the Relativistic Heavy Ion Collider (RHIC), at which most of the world's research in relativistic heavy-ion nuclear physics is performed; by supporting research and development of the next generation particle detectors, advanced accelerator technologies such as electron beam cooling, state-of-the-art electronics, software and computing; and by training scientists needed by the Nation's diverse high-skills industries and academic institutions.

Supporting Information

Historically, the first major milestone in establishing the idea for the formation of heated nuclear matter was marked in 1984 when scientists working at the Bevalac (LBNL) accelerator found the first direct evidence that nuclear matter can be compressed to high temperature and density using accelerated beams. This observation led to the studies of hot and extremely dense hadronic matter created in heavy-ion collisions with gold beams at the Alternating Gradient Synchrotron (BNL) in 1992 and at the CERN Super Proton Synchrotron (SPS) in 1994. These tiny "fireballs" equilibrated rapidly, suggesting that the right conditions should exist at even higher beam energies to create a new phase of metamorphosed matter called the quark-gluon plasma—named in the popular press as the mini "Big Bang," since this primordial form of matter is thought to have existed shortly after the birth of the universe.

A new program of research on hot nuclear matter began at the Relativistic Heavy Ion Collider (RHIC) at BNL in 2000 when the first collisions of counter-circulating gold nuclei were observed at beam energies 10 times higher than those available at any other facility in the world. While the RHIC facility puts heavy-ion research at the highest energy frontier, it is also the only facility in the world that provides collisions of polarized protons with polarized protons. This unique capability will allow information to be obtained on the intrinsic arrangement of gluons that bind quarks into a nucleon (a proton or a neutron). At the opposite end of the temperature scale, limited studies into the conditions for inducing the liquid-to-gas phase transition in nuclear matter are underway at the National Superconducting Cyclotron Laboratory (NSF funded) at Michigan State University, at Texas A&M University, and at foreign laboratories.

The construction of RHIC was completed in August 1999 and four successful running periods have been completed: Run 1 in FY 2000 with gold beams; Run 2, which spanned the end of FY 2001 and the beginning of FY 2002, with gold beams and commissioning of polarized protons; and Run 3 in FY 2003, with deuteron-gold collisions and the first physics results with polarized proton collisions; and Run 4 in FY 2004 with high luminosity gold beams and polarized protons. This facility is utilized by over 1,100 DOE, NSF and foreign agency supported researchers. Capital equipment and accelerator improvement project (AIP) funds are provided for additions, modifications and improvements to various accelerator components and systems that comprise the RHIC complex and ancillary experimental facilities, in order to maintain safety, improve the reliability and efficiency of operations, and provide new experimental capabilities. Beam time at the RHIC facility is allocated with guidance from a Program Advisory Committee, consisting of scientists that review and evaluate experiments regarding their merits and scientific priority. An annual review of the effectiveness of RHIC operations and its research is conducted by the program office and its recommendations are used to improve the RHIC program.

The Heavy Ion Nuclear Physics subprogram also provides general purpose equipment (GPE), general plant project (GPP), and other funding as part of Nuclear Physics' stewardship responsibilities for Brookhaven National Laboratory. These funds are for general purpose equipment, minor new capital fabrication, alterations and additions, improvements to land, buildings, and utility systems, and other normal operations that are needed for effective laboratory operations.

FY 2004 Accomplishments

The NSAC Long-Range plan identified several discoveries that support the goals of the Heavy Ion subprogram:

- Production of small regions of space with energy densities more than twenty times that of atomic nuclei. Matter under these extreme conditions may well be in the quark-gluon plasma phase.

- Observation of a strong “flow” of matter in relativistic heavy-ion collisions, indicating that the initial kinetic energy of the beams is rapidly converted to heating the nuclear matter created in the collision zone, putting it under immense internal pressure.
- Observation of a deficit of high transverse-energy particles in relation to proton-proton collisions. This result indicates that high-energy particles suffer energy losses much larger than those expected for the partons (making up the particles) passing through normal nuclear matter – hinting at the formation of the plasma phase in the collision.
- Measurements of anti-matter to matter ratio. Since the number of anti-baryons (anti-matter) is almost equal to the number of baryons (matter), it is concluded that the collision zone immediately after the collision consists of almost pure energy, from which particle-antiparticle pairs are produced.

These discoveries have been extended by the wealth of exciting new results reported from subsequent running periods at RHIC. The third running period in FY 2003 successfully collided deuterons with gold nuclei—a landmark technical accomplishment in itself—allowing scientists to report preliminary, but tantalizing results of central importance to the whole RHIC program. The fourth running period in FY 2004 with high luminosity gold beams produced large volumes of data that will afford observations of rare processes. In FY 2004, RHIC produced record luminosities. Some of the highlights from the gold-gold and deuteron-gold programs are:

- First measurements of jet tomography: Measurements of a spray of highly energetic particles emitted back-to-back (“jets”) have been measured with gold-gold collisions. Because “jet” phenomena occur at very early times, they are harbingers of the environment in which they are born. In the most violent head-on collisions one jet is “lost”. One explanation presumes that dual jets are, in fact, created near the surface of the hot, dense collision zone where one of the jets plows into an unusually opaque form of matter while the other jet escapes unimpeded in the opposite “matter-free” direction. New results indicate that the observed suppression depends on the orientation of the in bound jet and thus on its path length in the opaque media. Scientists hope to exploit this behavior using the large amount of data accumulated in FY 2004 to build a more detailed “tomographic” image of the opaque matter.
- Direct photons observed: First measurements have been made of energetic gamma rays emanating from head-on gold collisions. These “direct” photons are not suppressed and their rate is in agreement with theoretical expectations of radiation emitted from quarks and gluons.
- Reconstruction of charmed mesons: D mesons and J/ψ particles containing at least one heavy charm quark have been reconstructed in analysis of deuteron-gold collisions. These results will allow scientists to study the behavior and energy loss of heavy quarks in the dense, hot matter created in gold-gold collisions using the high statistics data acquired in FY 2004.
- Opposite behaviors observed in gold-gold and deuteron-gold collisions: One of the most dramatic results to emerge from RHIC has been the observation of a suppression of high momentum particles in gold-gold collisions relative to the expected scaling from proton-proton collisions. This behavior is not seen in the deuteron-gold control experiment where high density matter is not expected to be created. These results suggest the gold-gold collisions are influenced by new effects, such as those leading to the formation of quark-gluon plasma or other new forms of matter.
- First results reported from low energy gold-gold collisions: With the use of high speed computers to process and analyze large volumes of data, RHIC experimenters have obtained preliminary results

from 31 GeV/nucleon gold collisions in a record short time. This “energy scan” allows scientists to control the density and initial temperature of the collisions.

FY 2004 Facility and Technical Accomplishments:

- RHIC sets new machine record surpassing its design luminosity: RHIC in its latest run with 100 GeV/nucleon gold beams delivered twice the luminosity called for in its design goal. This record breaking performance in FY 2004 has exceeded all expectations and accordingly provided significantly more data for the experiments. Building on its past 4 years of technical achievements, RHIC has increased its delivered integrated luminosity per run by almost 200-fold.
- RHIC provides collisions of low energy gold beams: After the full energy gold run, RHIC successfully delivered first gold beams at 31 GeV/nucleon. Collisions were quickly established with luminosities high enough that allowed collection of new physics data.
- Proton beams with increased polarization achieved at RHIC: Following the deployment of complex magnets, called “Helical Spin Rotators” in FY 2003, a special magnet called the “Warm Snake,” built in collaboration with RIKEN (Japan) scientists and engineers, was installed in the Alternating Gradient Synchrotron (AGS). With this device, the average polarization of the proton beam in the RHIC ring has increased to 45%, almost double last year’s performance. A new polarized hydrogen jet target which will allow an absolute and accurate measurement of the proton beam polarization has been commissioned at RHIC.
- The STAR detector Electromagnetic Calorimeter Enhancement is completed: This MIE project was completed within cost and on schedule in FY 2004. Installation tasks will be completed in FY 2005, as planned.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research	**30,376**	**33,310**	**33,268**
▪ **University Research**	**12,392**	**12,720**	**12,113**

Support is provided for the research of about 120 scientists and 75 graduate students at 26 universities in 18 states. Support for university research is decreased by 4.8% ($607,000) compared with FY 2005.

- Researchers using relativistic heavy-ion beams are focused on the study of the production and properties of hot, dense nuclear matter at experiments at RHIC, where an entirely new regime of nuclear matter might be created for the first time. The university groups provide scientific personnel needed for the operation of the RHIC detectors, data analysis and publication of results.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- Research conducted at the NSF supported National Superconducting Cyclotron Laboratory at Michigan State University, at the DOE supported Texas A&M University, and at foreign facilities in France and Italy, that investigate nuclear reactions at intermediate energies with the aim of studying the fragmentation of nuclei and the behavior of nuclear matter at high baryon density has successfully addressed the most compelling questions and will be phased out.

  A limited effort in R&D and computer simulations directed at the relativistic heavy-ion program at the Large Hadron Collider at CERN is supported.

	FY 2004	FY 2005	FY 2006
▪ **National Laboratory Research**	**17,984**	**16,673**	**17,546**

Support is provided for scientists at five national laboratories (BNL, LBNL, LANL, LLNL and ORNL). These scientists provide essential manpower for the operations of the RHIC detectors: analyzing data and publishing scientific results; conducting R&D of innovative detector designs, integrated electronics designs for high bandwidth data acquisition systems and software technologies; as well as planning for future experiments. Also, BNL, LBNL, and LLNL provide substantial computing infrastructure for terabyte-scale data analysis and state-of-the-art facilities for detector and instrument development. Support is provided for computer simulations and R&D for a proposed relativistic heavy-ion program at the Large Hadron Collider at CERN that will begin data taking in 2008.

	FY 2004	FY 2005	FY 2006
• **BNL RHIC Research**	**8,171**	**6,231**	**8,474**

BNL scientists play a major role in planning and carrying out research with the four detectors (STAR, PHENIX, BRAHMS and Phobos) at RHIC and have major responsibilities for maintaining, improving and developing this instrumentation for use by the user community. In FY 2006 funding for capital equipment increases by $2,400,000 (partly from redirected facility operations), to start fabrication of the STAR Time-of-Flight (TOF) detector MIE project (TEC and TPC of $4,800,000). Support for researchers decreases by 6.5% ($422,000), resulting in the phaseout of support for the smaller detectors BRAHMS and Phobos. The initial survey work with gold and lighter nuclear beams at the full energy will be largely complete by FY 2005 and measurements of the yields of rarer signals, such as the expected J/ψ (psi) suppression due to its breakup by the quark-gluon plasma, and the characterization of “jets” will dominate the experimental program with the utilization of the currently enhanced RHIC detectors. Research, development, and design for detector upgrades is being performed by scientists from BNL, and other national laboratories, and universities, to add or enhance measurement capabilities that will allow the extraction of a broader variety of rare, but detectable signals that could become measurable at high RHIC luminosity.

The STAR Time-of-Flight (TOF) outer barrel detector MIE, based on Multi-gap Resistive Plate Chamber (MRPC) technology developed at CERN for A Large Ion Collider Experiment (ALICE), at the Large Hadron Collider, will extend particle identification of the particles tracked in the existing Time Projection Chamber (TPC) to much higher transverse momentum (up to 10 GeV/c) and provide electron tagging capability. Excellent results (timing resolution) have been obtained from a prototype unit (covering 1/60 of the barrel circumference) from the FY 2003 deuteron-gold run.

	FY 2004	FY 2005	FY 2006
• **Other National Laboratory Research**	**9,813**	**10,442**	**9,072**

(dollars in thousands)

Researchers at LANL, LBNL, LLNL, and ORNL provide unique expertise and facilities in the development of new technologies for RHIC detector upgrades, as well as playing leadership roles in the on-going research program. At LBNL, a large scale computational system, Parallel Distributed Systems Facility (PDSF), is a major resource used for the analysis of RHIC data, in alliance with the National Energy Research Scientific Computing Center (NERSC). At LLNL substantial computing resources are made available for the PHENIX data analysis. Compared to FY 2005 support for laboratory research decreases by 13.1% resulting in significant reductions in laboratory research groups.

▪ **Other Research**..	**0**	**3,917**	**3,609**

In FY 2004 funds were transferred to the SBIR program ($3,879,000). This section includes $3,917,000 for SBIR in FY 2005 and $3,609,000 for SBIR in FY 2006.

Operations	**131,075**	**141,240**	**128,611**
▪ **RHIC Operations**...	**120,547**	**130,473**	**117,868**

The Relativistic Heavy Ion Collider (RHIC) is a unique world-class scientific research facility that started its research program in 2000. Its colliding beams of relativistic heavy ions allow scientists an opportunity to explore and understand the nature of hot, dense matter and to recreate conditions under which nuclear matter dissolves into the predicted quark-gluon plasma. The first 3 initial survey runs have already produced 70 refereed journal papers, creating interest in the scientific community. Run 4 in FY 2004 set a new record for delivered integrated luminosity with gold beams that has surpassed the design goal by a factor of 2. This high level of performance allowed sufficient time to run RHIC at the lower beam energy of 31 GeV/nucleon. During the later part of Run 4 RHIC provided 100 GeV polarized proton beams. The successful installation of the “warm snake” magnet in the AGS has increased the beam polarization in the RHIC rings to 45%. Initial measurements with the new polarized gas-jet target, needed for an absolute calibration of the spin polarization of the proton beam, were completed. The RHIC facility, the first collider using two intense ion beams since the CERN Intersecting Storage Ring (ISR) of the 1970’s, is providing new information in the development of accelerator technology that will be directly useful in the operation of the Large Hadron Collider at CERN that will begin operation of the LHC heavy ion program in 2008.

• **RHIC Accelerator Operations**	**90,435**	**98,375**	**88,193**

Support is provided for the operation, maintenance, improvement and enhancement of the RHIC accelerator complex. This includes the Tandem, Booster and AGS accelerators that together serve as the injector for RHIC. FY 2006 funding will support 1,400 hours of operations, a 31% utilization of the collider. Increases in power costs and in medical insurance rates in FY 2006 contribute to the reduction in operating hours. Effective operation will be achieved by combining FY 2006-FY 2007 running into a single back-to-back run bridging the two Fiscal Years. This funding also supports $1,850,000 for R&D activities towards increasing the luminosity of the collider beyond its baseline design specifications. Capital equipment is reduced by 6.5% to $1,122,000 compared to FY 2005 and accelerator improvement (AIP) funding is decreased by $2,100,000 to $1,000,000.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

The accelerator improvement funds are being redirected to provide $2,000,000 towards the construction of the Electron Beam Ion Source (EBIS) that will replace the aging Tandem Van de Graaff as the heavy-ion source for the RHIC complex, providing higher intensities, better reliability and savings of ~$2,000,000 per year in RHIC operations. NASA has indicated interest in partially supporting this project because of the benefits to its Space Radiation Laboratory.

	FY 2004	FY 2005	FY 2006
RHIC Hours of Operation with Beam................	3,186	3,600	1,400

• **RHIC Experimental Support**......................	**30,112**	**32,098**	**29,675**

Support is provided for the operation, maintenance, improvement and enhancement of the RHIC experimental complex, including detectors, experimental halls, computing center and support for users. The RHIC detectors (STAR, PHENIX, BRAHMS and Phobos) have reached their initial planned potential and about 1,100 scientists and students from 82 institutions and 19 countries participate in the RHIC research program. These four detectors (described in the Site Descriptions) provide complementary measurements, but with some overlap in order to cross-calibrate the measurements. Compared with FY 2005, funding for researchers and material supplies in experimental support is reduced by -$1,531,000 (-5.6%) reflecting staff reductions, the phaseout of BRAHMS and Phobos operations, and a shorter running period in FY 2006. In FY 2006, funding for capital equipment is decreased by $892,000 (-20%) to $3,633,000 compared with FY 2005 and redirected to start the STAR TOF MIE.

▪ **Other Operations**	**10,528**	**10,767**	**10,743**

As steward for Brookhaven National Laboratory (BNL), the Nuclear Physics program provides general plant project (GPP), general purpose equipment (GPE) and other funding for minor new fabrication, other capital alterations and additions, and for buildings and utility system, for needed laboratory equipment and other expenses. Funding of this type is essential for maintaining the productivity and usefulness of Department-owned facilities and for meeting its requirement for safe and reliable facilities operation. In FY 2006 funding for GPP is increased by 4.1% ($260,000) to $6,617,000 relative to FY 2005.

Total, Heavy Ion Nuclear Physics............................	**161,451**	**174,550**	**161,879**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Research	
▪ **University Research**	
FY 2006 funding for grants for University Research decreases by 4.8%, with the phase out of research that investigates nuclear reactions at intermediate energies with the aim of studying the fragmentation of nuclei and the behavior of nuclear matter at high baryon density. The focus of research will be on the RHIC program with the two large detectors STAR and PHENIX as the analysis of data from the two smaller detectors will be nearing completion.	-607
▪ **National Laboratory Research**	
• BNL RHIC Research: Research support for scientific/technical personnel is decreased by 2.5% ($157,000) from FY 2005. Funding for capital equipment is increased by $2,400,000, with the start of the STAR Time-of-Flight (TOF) Major Item of Equipment (MIE) detector project.	+2,243
• Other National Laboratory Research: Support for research operations is decreased by 13.8% (-$1,402,000) compared to FY 2005, with reductions of scientific/ technical staff in laboratory groups. Funding for capital equipment increases by $32,000 to $307,000, compared to FY 2005.	-1,370
Total, National Laboratory Research	**+873**
▪ **Other Research**	
Estimated SBIR obligations decrease.	-308
Total, Research	**-42**
Operations	
▪ **RHIC Operations**	
• Accelerator Operations decrease 10.3% compared with FY 2005. This includes decreases of: $2,100,000 in accelerator improvement project (AIP) funds to $1,000,000 (of which $2,000,000 was redirected to the EBIS); $7,884,000 in accelerator operating funds for 31% of optimal operations; $120,000 in R&D activities relating to the collider luminosity; and $78,000 in capital equipment funds.	-10,182

	FY 2006 vs. FY 2005 ($000)
• Experimental Support: A 5.6% (-$1,531,000) decrease in funding for experimental scientific/technical staff and materials support compared with FY 2005 provides for running at 31% utilization with two detectors operating. A decrease of $892,000 in capital equipment funds reflects the decreased support for computing needed with the shorter FY 2006 run, and are redirected to start the STAR TOF MIE.	-2,423
Total, RHIC Operations	**-12,605**
▪ **Other Operations**	
FY 2006 funding for general plant projects at Brookhaven National Laboratory is increased by 4.1% ($260,000) to $6,617,000, compared with FY 2005, to address the backlog of needed infrastructure improvements. Funding for general purpose equipment at Brookhaven National Laboratory is decreased by $284,000 compared with FY 2005.	-24
Total, Operations	**-12,629**
Total Funding Change, Heavy Ion Nuclear Physics	**-12,671**

Low Energy Nuclear Physics

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Low Energy Nuclear Physics					
Research					
University Research	18,334	18,776	17,113	-1,663	-8.9%
National Laboratory Research	22,273	24,550	23,440	-1,110	-4.5%
Other Research	6,655	8,555	5,649	-2,906	-34.0%
Total, Research	47,262	51,881	46,202	-5,679	-10.9%
Operations	23,791	24,101	22,335	-1,766	-7.3%
Total, Low Energy Nuclear Physics	71,053	75,982	68,537	-7,445	-9.8%

Description

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

(1) What is the structure of nucleonic matter? The forefront of nuclear structure research lies in studies of nuclei at the limits of energy, deformation, angular momentum, and isotopic stability. The properties of nuclei at these extremes are not known and such knowledge is needed to test and drive improvement in nuclear models and theories about the nuclear many-body system.

(2) What is the nuclear microphysics of the universe? Knowledge of the detailed nuclear structure, nuclear reaction rates, half-lives of specific nuclei, and the limits of nuclear existence at both the proton and neutron drip lines is crucial for understanding nuclear astrophysics processes such as the production of the chemical elements in the universe, and the explosive dynamics of supernovae.

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

Benefits

The Low Energy subprogram supports the mission of the Nuclear Physics program by fostering fundamental research to obtain new insight into the structure of nucleonic matter, the nuclear microphysics of the universe, and fundamental tests for new physics. This subprogram supports a broad range of experiments at two national user facilities, the Holifield Radioactive Ion Beam Facility and the Argonne Tandem Linac Accelerator System, one other laboratory accelerator facility, four university-based accelerators, and non-accelerator based facilities such as the Sudbury Neutrino Observatory in Canada and KamLAND in Japan. The development of advanced accelerator technologies is also supported, including key technologies needed for the proposed new Rare Isotope Accelerator (RIA) facility. The Low Energy subprogram is an important source of trained scientific/technical personnel which contributes to a wide variety of nuclear technologies, national security, and environmental quality programs of interest to the DOE.

Supporting Information

Progress in both nuclear structure and astrophysics studies depend upon the availability of exotic beams, or beams of short-lived nuclei, to produce and study nuclei that lie in unstudied regions of the nuclear chart and are involved in important astrophysics processes. While the U.S. today has facilities with limited capabilities for these studies, it was already noted in the NSAC 1996 Long Range Plan for Nuclear Science that a facility with next generation capabilities for short-lived radioactive beams will be needed in the future for the U.S. to maintain a leadership role. In FY 1999, a NSAC Taskforce established the optimal technical option for such a facility, the Rare Isotope Accelerator (RIA) facility. The NSAC 2002 Long Range Plan identified RIA as the highest Nuclear Physics priority for a major new construction project. Starting in FY 2000, R&D activities have been supported in preparation for a possible request for approval for construction. Continued funding for R&D activities is provided in FY 2006. In an era of constrained budgets the Nuclear Physics program needs to develop a strategic plan for implementing its vision for the future. Guidance will be sought from NSAC regarding opportunities and priorities for the Nuclear Physics program in the context of fiscal constraints.

The research of this subprogram is generally conducted using beams provided by accelerator facilities either operated by this subprogram or by other domestic or foreign facilities. In FY 2006 the Low Energy Nuclear Physics subprogram supports the operation of two national user facilities: the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory and the Argonne Tandem Linac Accelerator System (ATLAS) facility at Argonne National Laboratory. These facilities are utilized by DOE-, NSF-, and foreign-supported researchers. The allocation of beamtime is made with the guidance of Program Advisory Committees, consisting of scientists, who review and evaluate proposed experiments regarding their merit and scientific priority. Capital equipment funds are provided for detector systems, for data acquisition and analysis systems, and for accelerator instrumentation. In FY 2006, fabrication continues for the Major Item of Equipment (MIE) project, the Gamma Ray Energy Tracking In-Beam Nuclear Array (GRETINA), a segmented germanium detector array with improved position resolution and efficiency for studies with fast fragment nuclear beams. Accelerator improvement project (AIP) funds are provided for additions, modifications, and improvements to the research accelerators and ancillary equipment facilities to maintain and improve the reliability and efficiency of operations, and to provide new accelerator capabilities. The 88-Inch Cyclotron (LBNL) made the transition in FY 2004 from a user facility to a facility for testing electronic circuit components for radiation “hardness” to cosmic rays, supported by the National Reconnaissance Office and the Air Force, and a small in-house research program supported by NP. Continued utilization of the facility for these activities is proposed for FY 2006.

University-based research is an important feature of the Low Energy subprogram. Accelerator operations have been supported at Texas A&M University (TAMU), the Triangle Universities Nuclear Laboratory (TUNL), University of Washington, and Yale University. In FY 2006 the case for terminating support of operations of one of these university facilities in order to provide resources to optimize the scientific productivity of the remaining facilities will be examined. 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.

The Low Energy subprogram also supports studies of fundamental interactions and symmetries in selected nuclei: “laboratories” that allow precise measurements to test the present understanding of the

Standard Model. Some experiments use accelerators in conjunction with special apparatus to study fundamental nuclear and nucleon properties, for example the ultra-cold neutron trap at the Los Alamos Neutron Science Center (LANSCE) at Los Alamos National Laboratory. In FY 2006, fabrication continues for the Fundamental Neutron Physics Beamline (FNPB) MIE at the Spallation Neutron Source that will enable measurements of fundamental properties of the neutron. Other experiments in Low Energy nuclear physics do not require the use of accelerators: the Sudbury Neutrino Observatory (SNO) detector is studying the production rate and properties of solar neutrinos, while the Kamioka Large Anti-Neutrino Detector (KamLAND) is studying the properties of anti-neutrinos produced by nuclear power reactors.

Research in the Low Energy subprogram continues to evolve to address forefront scientific questions. The 1990's began with research efforts at the 88-Inch Cyclotron, ATLAS, and other facilities to identify and characterize rapidly rotating superdeformed nuclei that have elongated football shapes. These spectroscopic studies have led to a deeper understanding of nuclear structure at high spin and large deformation. In 1997, the HRIBF facility became operational and is now producing over 100 proton-rich and neutron-rich radioactive beams. Research at these three facilities has explored nuclei at the extremes of nuclear spin, deformation, stability, and excitation energy. Stable beams and the first radioactive beams in the mid-1990's enabled nuclear structure and cross-section experiments to determine the nuclear reaction paths and some rates for the breakout from the stellar carbon-nitrogen-oxygen (CNO) cycle that leads to production of heavier elements. In neutrino physics, following the pioneering work on solar neutrinos with radiochemical experiments, the SNO experiment, conceived in the late 1980's to search for neutrino flavor oscillations, was designed and built in the 1990's. In 2001, SNO reported its first physics results, which together with other experimental results, made a persuasive case for neutrino oscillations among their different types (or "flavors") and thus showed that neutrinos have mass. These results have been confirmed by new measurements reported in 2002 and 2003 from SNO that are sensitive to the different types of neutrinos, and from the first KamLAND results with reactor produced anti-neutrinos. These results have stimulated an increasing interest in non-accelerator experiments, particularly those that study neutrino properties. Studies with both SNO and KamLAND continue in order to extend and refine measurements of neutrino oscillation parameters.

FY 2004 Accomplishments

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

- Studies of nuclei at extreme conditions are pointing to alterations of the nuclear shell structure, the ability of heavy nuclei to sustain rapid rotation demonstrating unexpected stability, and evidence for phase transitional behavior between spherical and deformed nuclei.
- Nuclear measurements of very neutron-rich, unstable nuclei, combined with new computational techniques, are leading to a better identification of the r-process site or sites for nucleosynthesis in stars and to quantitative models for the production of heavy elements.
- Measurements of solar and reactor neutrinos have indicated that neutrinos change their identity on the way from their source to the experiment detector, implying that they have mass, and providing a key to the fundamental structure of the forces of nature.

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

- Measurement of the $^{14}N(p,\gamma)^{15}O$ reaction rate: The $^{14}N(p,\gamma)^{15}O$ reaction rate is the slowest among the carbon-nitrogen-cycle reactions in stars, and impacts stellar structure and evolution. Recent measurements at the Triangle Universities Nuclear Laboratory indicate that the reaction rate currently used in stellar models is 20-40% too high. Use of the new value in stellar evolution models results in an increase in the age of globular clusters of stars from 10.1 gigayears to 10.9 gigayears, implying an increase in the lower limit of the age of the universe to 12 gigayears. The result, deduced using this independent approach, strengthens arguments that the globular-cluster ages rule out the possibility of a flat, matter-dominated universe.
- Dependence of the spin-orbit potential on neutron excess: The spin-orbit potential describes how the interaction of single-particle states in a nucleus depends on the coupling of a particle's spin with its angular momentum. A study by Argonne National Laboratory and Yale University researchers indicates a decrease in the spin-orbit strength for the $g_{7/2}$ and $h_{11/2}$ proton orbitals in nuclei with increasing numbers of neutrons beyond stability. The spin-orbit strength was previously believed to be independent of neutron number.
- Experiments with radioactive germanium beams: Neutron-rich germanium nuclei lie along the stellar r-process pathway that leads to the production of heavy elements in stars. The first single-particle transfer reaction and Coulomb excitation measurements have been carried out with chemically-purified, mass-separated short-lived ^{82}Ge nuclei (half life of 4.6 seconds) at the Oak Ridge National Laboratory. These experiments provide some of the first nuclear structure data for these germanium nuclei that are relevant to understanding the r-process.
- Measurement of the g-factor of an accelerated radioactive nucleus: The magnetic moment (g-factor) of a nuclear level depends on its detailed nuclear structure, and can indicate nuclear structure evolution with a change in the number of neutrons or protons. The first measurement with an accelerated radioactive beam of the g-factor of a short-lived nucleus has been carried out by a collaboration of university and laboratory researchers at the 88-Inch Cyclotron lead by Rutgers University. The experiment with 15-hour ^{76}Kr determined the g-factor of the first 2+ state in that nucleus to be similar to those of the heavier stable krypton nuclei.

FY 2004 Facility and Technical Accomplishments

- A new class of superconducting accelerating cavities: Double-spoke superconducting accelerating cavities, a new class of accelerating structures for linear accelerators, have been developed at the Argonne National Laboratory. These cavities, designed to accelerate heavy-ion particles traveling 40-60% the speed of light, have demonstrated superior performance in both high accelerating gradient and low sensitivity to vibration.
- Neutral current detectors installed in the Sudbury Neutrino Observatory (SNO) detector: Neutral current detectors (NCDs), consisting of strings of ^{3}He neutron counters, have been installed in the SNO detector that contains 1,000 tons of heavy water, water with ordinary hydrogen replaced by deuterium. The NCDs will enable the SNO experiment to make an independent measurement of neutrinos as they change from one type to another (oscillate), and reduce the uncertainties on oscillation parameters. The NCD system underwent commissioning, and started taking data in the fall of 2004 for a two year running period. The NCDs were fabricated by a collaboration of U.S. universities and laboratories led by the University of Washington. The SNO experiment involves scientists from Canada, the United States, and the United Kingdom and is located in a deep nickel mine in Canada.

- Fabrication of GRETINA: In FY 2004, the Gamma-Ray Energy-Tracking In-beam Nuclear Array (an MIE) was started. GRETINA is a segmented germanium detector array that offers increased position resolution and efficiency for measuring high energy gamma rays. GRETINA is being fabricated at the Lawrence Berkeley National Laboratory in collaboration with Argonne National Laboratory and Oak Ridge National Laboratory.
- Fabrication of the Fundamental Neutron Physics Beamline (FNPB): In FY 2004, the FNPB (an MIE) was started at the Spallation Neutron Source. The beamline, being fabricated at Oak Ridge National Laboratory, will allow the measurement of fundamental properties of the neutron.
- Detection techniques and methods to measure a radiological release: Techniques and methods have been developed at the Lawrence Berkeley National Laboratory to use automotive air filters to determine the severity and extent of a radiological release. Filters from vehicles that travel defined routes or areas, such as police cars, are assayed by sensitive radiation detectors to map and quantify radioactivity in the environment. This work could make possible a low-cost method to implement a nation-wide system to respond to radiological release events.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Research	**47,262**	**51,881**	**46,202**
▪ **University Research**	**18,334**	**18,776**	**17,113**

Support is provided for the research of about 110 scientists and 85 graduate students at 25 universities. Nuclear Physics university scientists perform research as users at national laboratory facilities, at on-site facilities and at other specifically fabricated experiments. These activities address a broad range of fundamental issues as diverse as the properties of nuclei, the nature of the weak interaction, the production mechanisms of the chemical elements in stars and supernovae, and the properties of neutrinos. FY 2006 funding for operation of university accelerator facilities and for researchers and students is decreased 6.1% compared to FY 2005, resulting in a ~9% reduction in existing Ph.D. researchers and graduate students. Research activities are described below.

- Research programs are conducted using the low energy heavy-ion beams and specialized instrumentation at the national laboratory user facilities supported by this subprogram (the ANL-ATLAS and ORNL-HRIBF facilities). The effort at the user facilities involves about two-thirds of the university scientists supported by this subprogram.
- Accelerator operations are supported for in-house research programs at universities: the University of Washington, the Triangle Universities Nuclear Laboratory (TUNL) facility at Duke University, Texas A&M University (TAMU) and Yale University. Each of these small university facilities has a well-defined and unique physics program, providing light and heavy-ion beams, specialized instrumentation and opportunities for long-term measurements that complement the capabilities of the national laboratory user facilities. Equipment funds are provided for new instruments and capabilities.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- Involvement in other accelerator and non-accelerator experiments directed at fundamental measurements, such as measurements of solar neutrino rates and the neutrino mass at the Sudbury Neutrino Observatory (SNO) in Canada, are supported. The U.S. effort with the Kamioka Large Anti-Neutrino Detector (KamLAND) in Japan is being supported jointly with the High Energy Physics program.

▪ **National Laboratory Research**	**22,273**	**24,550**	**23,440**

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

• **National Laboratory User Facility Research**..	**13,797**	**14,034**	**13,350**

Scientists at ANL, LBNL, and ORNL have major responsibilities for maintaining, improving and developing instrumentation for research by the user communities at the user facilities, as well as playing important roles in carrying out research that addresses the program's priorities. In FY 2006 funding is decreased by 4.9% for personnel compared with FY 2005. Support is provided for the following research activities.

- ► At ORNL the research focuses on the use of radioactive beams from the HRIBF and specialized spectrometers to study the nuclear structure of nuclei far from stability. Measurements are made of reaction cross sections and nuclear properties, such as half-lives, which are crucial input to detailed astrophysics models that calculate the production of the elements in stars. Specialized equipment is employed, such as a system that integrates gamma-ray and charged-particle detectors with a recoil mass separator. The high-pressure gas target for nuclear astrophysics experiments is being utilized in an experimental program in nuclear astrophysics.
- ► At ANL the research focuses on the use of stable and selected radioactive beams from ATLAS, coupled to ion traps, Gammasphere and the Fragment Mass Analyzer to study fundamental processes and properties of nuclei, and to study nuclei at the extremes of excitation energy, angular momentum, deformation and isotope stability. Studies are undertaken with the Advanced Penning Trap, the successor to the Canadian Penning Trap, to measure atomic masses with high precision and search for effects in beta decay outside the standard decay model.
- ► At LBNL the research focuses on completion of data analyses; leadership in the fabrication of the GRETINA (MIE) detector and conduct of an in-house research program that includes heavy element nuclear physics and chemistry, and fundamental symmetry studies.

	FY 2004	FY 2005	FY 2006
• **Other National Laboratory Research**	**8,476**	**10,516**	**10,090**

(dollars in thousands)

Scientists at BNL, LBNL, LLNL, LANL and ORNL play important roles in a number of high-priority accelerator- and non-accelerator-based experiments (SNO, KamLand) directed toward fundamental questions. FY 2006 funding for scientific/technical staff decreases by 13.6% compared to FY 2005 for low energy accelerator and non-accelerator R&D activities significantly impacting what activities can be pursued. Critical personnel at LBNL are retained. Capital equipment investments increase from FY 2005 by $265,000 to $5,371,000, primarily for the fabrication of the GRETINA and FNPB MIEs. These activities are described below.

- ► The Sudbury Neutrino Observatory (SNO) experiment in Canada. The SNO detector, jointly built by Canada, England and the U.S., addresses the question of whether the observed reduced rate of solar neutrinos reaching the earth results from unexpected properties of the sun, or whether it results from a fundamental property of neutrinos–namely that neutrinos produced in the sun change their nature (that is, oscillate to a new neutrino type) during the time it takes them to reach the earth. This latter explanation would imply that the neutrinos have mass. In FY 2002, and 2003, the results from SNO with the heavy water detector were reported, indicating strong evidence for neutrino oscillations. In FY 2004, the third phase of SNO began; it will provide additional detail and confirmatory information on neutrino oscillations. Results from this phase are expected to be reported in FY 2007.
- ► The KamLAND experiment in Japan will measure the rate and properties of anti-neutrinos produced by several distant nuclear power reactors to study neutrino “oscillations.” KamLAND has the advantage of comparing the measured fluxes to known sources. Commissioning of the KamLAND detector began in FY 2002, with data collection continuing through FY 2005 with refined physics results likely to be reported in FY 2006. The U.S. participation in KamLAND is supported jointly with the High Energy Physics program.
- ► Research and development activities for the next generation neutrino detectors are being pursued at LBNL, PNNL and LANL as part of the possible suite of detectors to be located at the planned NSF-supported underground laboratory or other underground laboratory. There is also a limited advanced accelerator R&D effort at LBNL focused on ion sources.
- ► Neutron beams at the LANSCE facility at LANL are “cooled” to very low energies for new cold and ultra-cold neutron experiments, which will allow very precise measurements of fundamental neutron properties. Commissioning of neutron experiments with these beams began in FY 2004 and acquisition of first data is anticipated in FY 2005.

	FY 2004	FY 2005	FY 2006
	(dollars in thousands)		

- ► The Gamma-Ray Energy-Tracking In-beam Nuclear Array (GRETINA), for which fabrication began in FY 2004, is especially important for the study of the nuclear decay and structure of exotic nuclei in fast fragmentation beams. The improved position resolution and higher efficiency for high-energy gamma rays compared with presently available gamma-ray detector arrays will allow this new detector system to utilize fragmented nuclear beams to open up a new frontier for understanding exotic nuclei that may exist in stars and supernovae, but live only briefly (fractions of a second). In FY 2006 funding of $3,000,000 (TEC of $17,000,000; TPC of $18,200,000) is provided to continue fabrication of GRETINA (a Major Item of Equipment).

- ► The Fundamental Neutron Physics Beamline MIE at the Spallation Neutron Source will allow measurements of the fundamental properties of the neutron. Fabrication began in FY 2004 and continues in FY 2006 with funding of $1,900,000 (TEC of $9,200,000; TPC of $9,300,000).

	FY 2004	FY 2005	FY 2006
▪ **Other Research**..	**6,655**	**8,555**	**5,649**
• **RIA R&D Activities**.....................................	**5,905**	**6,736**	**4,000**

Funds are provided at the FY 2005 Congressional Request level for R&D activities aimed at a possible future Rare Isotope Accelerator (RIA) facility.

	FY 2004	FY 2005	FY 2006
• **SBIR and Other**...	**750**	**1,819**	**1,649**

In FY 2004 $1,092,000 was transferred to the SBIR program. This section includes $1,444,000 for SBIR in FY 2005 and $1,274,000 for SBIR in FY 2006 and other established obligations. The Lawrence and Fermi Awards, funded under this line, provide annual monetary awards to honorees selected by the DOE for their outstanding contributions to science.

	FY 2004	FY 2005	FY 2006
Operations	**23,791**	**24,101**	**22,335**
▪ **User Facility Operations**...................................	**23,641**	**23,951**	**22,185**

Support is provided for the operation of two National User Facilities, the Argonne Tandem Linac Accelerator System (ATLAS) at ANL and the Holifield Radioactive Ion Beam Facility (HRIBF) at ORNL, for studies of nuclear reactions, structure and fundamental interactions, with operations at 76% of optimal utilization, and for operation of the 88-Inch Cyclotron for an in-house nuclear physics program.

HRIBF has coupled the existing cyclotron and tandem accelerator to develop a focused radioactive-ion beam program. Both proton-rich and neutron-rich beams are provided to spectrometer systems, designed for nuclear structure studies, and the Daresbury Recoil Separator and the Silicon Detector Array for nuclear astrophysics studies. In FY 2006 accelerator improvement project funding is provided ($1,300,000) of which $1,100,000 will be used for the fabrication of a second source and transport beamline for radioactive ions.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

ATLAS provides stable heavy-ion beams and selected radioactive-ion beams for research. Experiments utilize ion traps, the Fragment Mass Analyzer, Gammasphere, and advanced detectors to study the structure of nuclei at the limits of stability, and fundamental and decay properties of nuclei. In FY 2006 accelerator improvement project funding is directed towards upgrading the accelerator to increase the radioactive beam capabilities of ATLAS.

Operations at the 88-Inch Cyclotron made a transition in FY 2004 from a national user facility to a facility providing beams for applied researchers and a limited in-house program. This was done to provide resources to optimize the utilization and science productivity of the remaining user facilities and to be consistent with the recommendations of the NSAC Low Energy Program Review in 2001. In late FY 2003 the National Reconnaissance Office (NRO) and the Air Force (USAF) determined that operation of the 88-Inch Cyclotron was essential for production of heavy-ion beams that could be used to simulate cosmic ray damage to electronic components that would be used in space. In this way circuits could be tested to determine if they were appropriately "hardened" to radiation in space. In the Memorandum of Understanding that was developed these offices would provide a total of $2,000,000 annually to maintain operations for 2,000 hours of operation of the Cyclotron for these tests in FY 2004 and FY 2005 and Nuclear Physics would provide $3,000,000 for a 3,000 hour in-house nuclear physics research program. A continued need for the beam capabilities of the 88-Inch Cyclotron has been determined and a Memorandum of Agreement for the continuation of this arrangement for FY 2006-2011 is being developed by the three parties for signature.

Included in the funding are capital equipment and accelerator improvement project funds provided to each of the operating facilities for the enhancement of the accelerator systems and experimental equipment. In FY 2006 these low energy facilities will carry out about 80 experiments involving about 300 U.S. and foreign researchers. Planned hours of operation with beam are indicated below:

	FY 2004	FY 2005	FY 2006
ATLAS Hours of Operation with Beam	6,195	5,600	5,700
HRIBF Hours of Operation with Beam	4,484	4,350	4,050
Total Beam Hours for Low Energy Facilities	10,679	9,950	9,750

	FY 2004	FY 2005	FY 2006
▪ **Other Operations**	**150**	**150**	**150**

Funding is provided for maintenance of the Oak Ridge Electron Accelerator (ORELA) for criticality measurements supported by DOE/NNSA.

	FY 2004	FY 2005	FY 2006
Total, Low Energy Nuclear Physics	**71,053**	**75,982**	**68,537**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Research	
▪ **University Research**	
FY 2006 funding for researchers and students is decreased 6.1% ($-1,055,000) compared to FY 2005 and capital equipment by 40% ($-608,000).	-1,663
▪ **National Laboratory Research**	
National Laboratory User Facility Research: FY 2006 funding decreases 4.9% compared to FY 2005 for research efforts and activities at the user facilities.	-684
Other National Laboratory Research: Research funding for personnel decreases 13.6% ($-741,000) in FY 2006 compared with FY 2005. Equipment funds are increased by $315,000 to address scientific opportunities identified in the NSAC 2002 Long Range Plan for Nuclear Science, such as the Fundamental Neutron Physics Beamline at the Spallation Neutron Source and the fabrication of the GRETINA gamma-ray tracking detector	-426
Total, National Laboratory Research	**-1,110**
▪ **Other Research**	
RIA R&D activities are supported at the FY 2005 Congressional Budget Request level ($4,000,000); a decrease of $-2,736,000 compared to FY 2005 Appropriations. Estimated SBIR and other obligations decrease by $-170,000.	-2,906
Total, Research	**-5,679**
Operations	
In FY 2006 operating funds are decreased by 9.6% ($1,642,000) compared to FY 2005 for ATLAS and HRIBF operations to provide an estimated 9,750 hours of beam time. Funding for capital equipment and accelerator improvement projects decreases by $124,000 compared to FY 2005.	-1,766
Total Funding Change, Low Energy Nuclear Physics	**-7,445**

Nuclear Theory

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Nuclear Theory					
Theory Research					
University Research	12,174	12,645	10,929	-1,716	-13.6%
National Laboratory Research	9,257	9,376	9,097	-279	-3.0%
Scientific Computing (SciDAC)	1,988	1,985	1,500	-485	-24.4%
Total, Theory Research	23,419	24,006	21,526	-2,480	-10.3%
Nuclear Data Activities	5,015	5,409	5,139	-270	-5.0%
Total, Nuclear Theory	28,434	29,415	26,665	-2,750	-9.3%

Description

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

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

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

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

(4) What is the microphysics of the universe? The theory subprogram attempts to understand the nuclear microphysics of the universe that involve fundamental nuclear physics processes, such as the

origin of elements; the structure and cooling of neutron stars; the properties of neutrinos from the sun and the mechanism of core-collapse supernovae.

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

Benefits

The Nuclear Theory subprogram cuts across all components of the Nuclear Physics mission to foster fundamental research in nuclear physics that will provide new insights and advance our knowledge on the nature of matter and energy. The theory groups and individual researchers at universities and DOE national laboratories strive to improve the theoretical techniques and gain new insights used to interpret data gathered by Nuclear Physics supported user facilities and the non-accelerator based experimental programs. By doing so, they not only advance our scientific knowledge and technologies, especially in the area of large scale computing, but serve to train the scientific/technical workforce needed for this research and indeed for an increasingly technological society. The mission of the nuclear data program, included within the theory subprogram, is also directly supportive of the DOE's missions for nuclear-related national security, energy, and environmental quality.

Supporting Information

The research of this subprogram is conducted entirely by groups and individual researchers located at universities and DOE national laboratories. The researchers utilize the high performance computational facility at the National Energy Research Scientific Computing Center (NERSC) at the Lawrence Berkeley National Laboratory and other specialized computers at other institutions. This subprogram sponsors the national Institute for Nuclear Theory (INT), based at the University of Washington, in Seattle, Washington, where visiting scientists focus on key frontier areas in nuclear physics, including those crucial to the success of existing and future experimental facilities and the education of postdoctoral researchers and graduate students. The subprogram is responding to the need for large dedicated computational resources for Lattice Quantum ChromoDynamical (LQCD) calculations that will be useful for understanding the experimental results from RHIC and TJNAF.

The program is enhanced through interactions with complementary programs overseas, with efforts supported by the National Science Foundation, with programs supported by the High Energy Physics program and with the Japanese supported theoretical efforts related to RHIC at the RIKEN Center at Brookhaven National Laboratory. Many foreign theorists participate on advisory groups as peer reviewers. There is large participation in the INT by researchers from Europe and Japan and by researchers in overlapping fields such as astrophysics, atomic and molecular physics, condensed matter physics and particle physics.

Included in the theory subprogram are the activities that are aimed at providing information services on critical nuclear data and have as a goal the compilation and dissemination of an accurate and complete nuclear data information base that is readily accessible and user oriented.

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

FY 2004 Accomplishments:

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

- Quantum Monte Carlo studies of Fermi gases: Determining the properties of Fermi gases is an intriguing topic for many-body physics, with applications to phenomena such as the outer crust of neutron stars, pairing in neutron rich nuclei, and to atomic gases trapped in controllable laboratory experiments. Recently researchers have conducted quantum Monte Carlo calculations of superfluid Fermi gases with short-range two-body attractive interactions with infinite scattering length. The energy of such gases is estimated to be (0.44 ± 0.01) times that of the noninteracting gas, and their pairing gap is approximately twice the energy per particle.
- Studies of hadronic structure on the lattice: An important question about the nucleon and its excited state, Δ, is whether they are spherical or deformed. Recent experiments carried out at TJNAF have accurately measured the electric and Coulomb quadrupole and magnetic dipole multipoles of the nucleon-to-Δ transition form factor, which directly reflect the presence of deformation. This form factor has recently been calculated using lattice QCD, a technique which solves the equations of QCD numerically on a granular space-time "lattice." The calculated magnetic dipole form factor and electric quadrupole amplitude were consistent with experimental results, but systematic errors due to limitations of this technique with present day computer resources (lattice artifacts) prevented a determination of the Coulomb quadrupole form factor. Further study of these lattice artifacts is needed for better control of systematic errors.
- Indicators of quark-gluon plasma formation: Over twenty years ago it was suggested that fast partons (quarks and gluons) traveling through a quark-gluon plasma (QGP) might lose a large amount of energy by elastic scattering with the plasma constituents, resulting in the suppression of jets from the interior of the collision fireball in relativistic heavy-ion collisions. Such a suppression of energetic particles has been observed in central gold-gold collisions at RHIC. The far-side partners of the observed jets are completely suppressed in central gold-gold collisions, but they are not suppressed in the collision of a very light nucleus (the deuteron) with a gold nucleus. The deuteron-gold results prove that these suppression patterns in gold-gold collisions are caused by final state interaction of hard partons with the produced dense medium. Theorists can now analyze the observed jet quenching phenomena with the aid of perturbative QCD to extract properties of the dense matter produced, an early step toward a tomographical picture of the hot and dense matter formed in heavy-ion collisions at RHIC. A recent study concludes that the initial gluon (energy) density of the hot matter produced in central gold-gold collisions that causes jet quenching at RHIC is about 30-100 times higher than in a cold gold nucleus. Combined with data on bulk and collective properties of the hot matter, the observed jet quenching provides strong evidence for the formation of a strongly-interacting quark-gluon plasma in central gold-gold collisions at RHIC.
- Origin of elements: Spectacular core-collapse supernovae explosions represent the violent end of a massive star's life, and create and disperse many elements – but the explosion mechanism remains elusive. Theoretical nuclear astrophysics, coupled with results from a variety of nuclear physics measurements, represents the foundation of an emerging generation of sophisticated, computationally intensive models of astrophysical phenomena. For example, nuclear theorists working under the DOE Scientific Discovery through Advanced Computing (SciDAC) program on simulations of exploding stars are continuing to make rapid progress on many fronts. An analytic reformulation of general relativistic kinetic theory has allowed the development of a new Boltzman

neutrino transport code suitable for two- and three-dimensional models of stellar collapse. Less sophisticated neutrino transport codes have previously been utilized in one-dimensional (spherical) models of stars. This large collaboration has also discovered in their numerical simulations two new fluid instabilities that may play an important role in supernova dynamics. These new computational tools could also be applied to other fields of research.

- In the past five years, the availability of enormous computing power has allowed theorists to make spectacular progress on problems that were previously thought intractable. It is now possible to simulate complex nuclear physics processes at extreme length scales ranging from astrophysical objects, to nuclei, to the quark structure of matter. The development of the Green's Function Monte Carlo Technique and the No-Core Shell Model as solutions to the nuclear many-body system for small numbers of nucleons, and the Monte Carlo Shell Model of nuclei are state-of-the-art computational methods that could provide a framework for a "Standard Nuclear Model" in the near future. In the last few years, large-scale parallel processor machines have been exploited to simulate QCD problems on a space-time lattice.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Theory Research	**23,419**	**24,006**	**21,526**
▪ **University Research**	**12,174**	**12,645**	**10,929**

The research of about 145 university scientists and 85 graduate students is supported through 58 grants at 46 universities in 26 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. Funding is decreased by 13.6% ($1,716,000) compared with FY 2005 resulting in ~14% reduction in the number of Ph.D. researchers and graduate students supported in FY 2006. Lower priority activities will be phased out in order to focus efforts on the high priority activities which are aligned with SC Strategic Plan milestones. Following a recommendation of the NSAC Theory Review subcommittee in its report "A Vision for Nuclear Theory," university funding has been redirected to begin investment in Lattice QCD capabilities.

The Institute for Nuclear Theory (INT) at the University of Washington hosts three programs per year where researchers from around the world attend to focus on specific topics or questions. These programs result in new ideas and approaches, the formation of collaborations to attack specific problems, and the opportunity for interactions of researchers from different fields of study. For example, recent programs have resulted in a new research effort that fuses modern shell model technology with effective field theory to potentially provide a tractable, rigorous solution for low energy properties of nuclei.

▪ **National Laboratory Research**	**9,257**	**9,376**	**9,097**

Research programs are supported at 7 national laboratories (ANL, BNL, LANL, LBNL, LLNL, ORNL and TJNAF). Funding for scientific/technical staff is decreased by 8.3% (-$779,000) compared with FY 2005. This decrease is offset, in part, by a significant program shift to begin a major IT investment in Lattice Quantum ChromoDynamics to establish new national computing

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

resources. The nuclear physics part of this effort, undertaken as a joint project with the High Energy Physics program, is an investment of $500,000.

- The range of topics in these programs is broad, and each of the active areas of experimental nuclear physics is supported by at least some of these nuclear theory activities.
- In all cases, the nuclear theory research at a given laboratory provides support to the experimental programs at that laboratory, or takes advantage of some unique facilities or programs at that laboratory.
- The larger size and diversity of the national laboratory groups make them particularly good sites for the training of nuclear theory postdoctoral associates.

▪ **Scientific Computing (SciDAC)**	**1,988**	**1,985**	**1,500**

Scientific Discovery through Advanced Computing (SciDAC) is an SC program to address major scientific challenges that require advances in scientific computing using terascale resources. In FY 2001 several major multi-institutional grants in high-priority topical areas were awarded through this program for the first time by the then combined High Energy and Nuclear Physics (HENP) programs. All current SciDAC projects will be completed in FY 2005 and a new competition will be held in FY 2006. Currently theoretical nuclear physics supports the National Computation Infrastructure for Lattice Gauge Theory (the gauge theory relevant to contemporary nuclear physics is QCD) and an award titled Shedding New Light on Exploding Stars: Terascale Simulation of Neutrino-Driven Supernovae and their Nucleosynthesis-TSI. Each award led to two of the achievements noted earlier, and the TSI endeavor appears to be in line with meeting an SC 2006 milestone to “develop three-dimensional computer simulation for the behavior of supernovae, including core collapse and explosion, which incorporate the relevant nuclear reaction dynamics.” These activities will be supported at a reduced level compared to FY 2005.

Nuclear Data Activities	**5,015**	**5,409**	**5,139**

The Nuclear Data program collects, evaluates, archives, and disseminates information on nuclear properties and reaction processes for the physics community and the nation. The focal point for its national and international activities is the DOE-managed National Nuclear Data Center (NNDC) at Brookhaven National Laboratory. Funding is decreased 5.0% ($270,000) resulting in personnel reductions for this activity. To protect training of new compilers for this activity, lower priority activities will be phased out at both universities and national laboratories, and one university grant and one task will be terminated. This is a critical issue, with over 50% of the compilers and evaluators over 60 years old, retired and working part-time. The NNDC relies on the U.S. Nuclear Data Network (USNDN), a network of DOE supported individual nuclear data professionals located in universities and national laboratories who perform data assessment as well as developing modern network dissemination capabilities.

The NNDC participates in the International Data Committee of the International Atomic Energy Agency (IAEA).

Total, Nuclear Theory	**28,434**	**29,415**	**26,665**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Theory Research	
▪ **University Research**	
FY 2006 funding is decreased 13.6% compared to FY 2005 resulting in reductions in the Ph.D. researchers and graduate students supported. Resources will be focused on the theoretical understanding of the research that was identified in SC Strategic Plan Milestones and to implement recommendations from the recent NSAC Subcommittee on Nuclear Theory.	-1,716
▪ **National Laboratory Research**	
FY 2006 funding overall is decreased 3.0% compared to FY 2005 resulting in reductions in scientific staff supported. Research will be directed toward achieving the scientific goals of the Nuclear Physics program, including implementing the Lattice Gauge Quantum ChromoDynamics initiative with HEP.	-279
▪ **Scientific Computing (SciDAC)**	
FY 2006 funding is decreased by 24.4% compared to FY 2005. There will be a reduction in the scope of activities supported utilizing the guidance of peer-review.	-485
Total, Theory Research	-2,480
▪ **Nuclear Data Activities**	
FY 2006 funding is decreased 5.0% compared to FY 2005 resulting in reductions in scientific researchers supported at universities and national laboratories. Efforts will be focused on maintaining capabilities to effectively evaluate, compile and disseminate nuclear data needed for basic and applied research	-270
Total Funding Change, Nuclear Theory	**-2,750**

Construction

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Construction (PED only)					
Electron Beam Ion Source (PED)	0	0	2,000	+2,000	--

Description

This provides for Project Engineering and Design for an upgrade at the Relativistic Heavy Ion Collider that is needed to meet overall objectives of the Nuclear Physics program.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Construction	**0**	**0**	**2,000**
▪ **Electron Beam Ion Source (PED)**	**0**	**0**	**2,000**

Funding of this line-item construction project would provide for Project Engineering and Design (PED) funding (TPC~$3,700,000, TEC~$3,500,000) of the Electron Beam Ion Source (EBIS). It is funded from redirected RHIC accelerator improvement project funds in order to replace the Tandem Van de Graaff as the source for heavy ions for RHIC, improving reliability and efficiency of operations, avoiding inevitable costly repairs of the aging tandem, thereby leading to more cost-effective operations. The full Total Estimated Cost (design and construction) ranges between $12,000,000 and $17,500,000; and the full Total Project Cost estimate (design and construction) ranges between $16,000,000 and $19,500,000. These estimates are based on preliminary data and should not be construed as a project baseline. NASA has indicated interest in possibly partially supporting this project. Additional information is contained in construction project datasheet 06-SC-02.

	FY 2004	FY 2005	FY 2006
Total, Construction	**0**	**0**	**2,000**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Construction	
▪ **Electron Beam Ion Source (PED)**	
Project engineering and design (PED) funds are provided for the Electron Beam Ion Source (EBIS) from re-directed AIP funds, to replace the aging Tandem Van de Graaff as the heavy-ion source for the RHIC complex.	+2,000

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	8,254	7,157	7,365	+208	+2.9%
Accelerator Improvement Projects	7,028	6,024	3,823[a]	-2,201	-36.5%
Capital Equipment	27,453	26,298	26,112	-186	-0.7%
Total, Capital Operating Expenses	42,735	39,479	37,300	-2,179	-5.5%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro- priations	FY 2004	FY 2005 Approp.	FY 2006 Request	Unappro- priated Balances
06-SC-02 PED, BNL, Electron Beam Ion Source	3,500[b]	0	0	0	2,000	1,500

[a] At BNL, Accelerator Improvement Funds are redirected to start the Electron Beam Ion Source Project.
[b] The full Total Estimated Cost (design and construction) ranges between $12,000,000 and $17,500,000; and the full Total Project Cost (design and construction) ranges between $16,000,000 and $19,500,000. These estimates are based on preliminary data and should not be construed as a project baseline.

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Accept-ance Date
STAR EM Calorimeter Enhancement	4,830	4,830	2,750	2,080	0	0	FY 2005
STAR Time-of-Flight	4,800	4,800[a]	0	0	0	2,400	FY 2008
GRETINA gamma-ray detector	18,200	17,000[b]	0	1,000	2,500	3,000	FY 2010
Fundamental Neutron Physics Beamline at Spallation Neutron Source	9,300	9,200[c]	0	1,000	1,200	1,900	FY 2010
Total, Major Items of Equipment				4,080	3,700	7,300	

[a] The total estimated cost is preliminary and will be baselined at a Technical, Cost and Schedule Review.

[b] The preliminary TEC was refined in the conceptual design effort and has increased by $2 million to $17 million during FY 2004, still within the $13 to $18 million range approved at CD-0 and CD-1. The TEC is preliminary and will be baselined at CD-2. The CD-2a for long lead procurements is planned for May 2005. CD-2 for the project as a whole is planned for July 2007.

[c] The preliminary TEC of $9.2 million is within the $8 to $11 million range approved at CD-0 and has been baselined at CD-2.

Fusion Energy Sciences

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Fusion Energy Sciences					
Science	142,723	156,301	-1,238[a]	155,063	142,771
Facility Operations	85,690	90,673	-730[a]	89,943	127,519
Enabling R&D	27,446	29,136	-239[a]	28,897	20,260
Total, Fusion Energy Sciences	255,859[b]	276,110	-2,207	273,903	290,550

Public Law Authorization:

Public Law 95-91, "Department of Energy Organization Act, 1977"

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

Mission

The Fusion Energy Sciences (FES) program is the national research effort to advance plasma science, fusion science, and fusion technology—the knowledge base needed for an economically and environmentally attractive fusion energy source. FES is pursuing this effort through collaborations with U.S. universities, industry, national research laboratories, and the international fusion community.

Benefits

Fusion is the energy source that powers the sun and stars. In the fusion process, forms of the lightest atom, hydrogen, fuse together to make helium in a very hot and highly charged gas or plasma. In the process, tremendous amounts of energy are produced. Fusion could play a key role in U.S. long-term energy plans and independence because it offers the potential for plentiful, safe and environmentally benign energy. The hydrogen isotopes deuterium and tritium, the fundamental fuel for a fusion reaction, are derived from sources as common and abundant as sea water and the earth's crust. Besides the advantages of an abundant fuel supply, the fusion process would produce little to no carbon emissions. A fusion power plant could be designed to shut down easily, have only short-lived radioactivity, and produce manageable radioactive waste. A science-based approach to fusion offers the most deliberate path to commercial fusion energy and is advancing our knowledge of plasma physics and associated technologies, yielding near-term benefits in a broad range of scientific disciplines. Examples include plasma processing of semiconductor chips for computers and other electronic devices, advanced video displays, innovative materials coatings, and the efficient destruction of chemical and radioactive wastes.

The FES program is also pushing the boundaries in large scale international scientific collaboration. With the support of a Presidential negotiating mandate, FES is actively leading a U.S. effort to provide manpower and components as in-kind contributions in the support of ITER—an international project to build and operate the first fusion science facility capable of producing an energy-generating, sustained burning plasma. Although site selection for ITER is still being decided, it is the objective of all

[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes reductions of $1,555,000 rescinded in accordance with the P.L. 108-137, Consolidated Appropriations Act, 2004, $5,979,000, which was transferred to the SBIR program, and $717,000 which was transferred to the STTR program.

international parties involved to reach consensus and finalize the ITER agreement in FY 2005. The "U.S. Contributions to ITER" is a proposed Major Item of Equipment (MIE) project, which supports the multilateral internationally-based project called ITER. The mission for ITER is to demonstrate the scientific and technological feasibility of fusion energy. In preparation for the start of ITER and the U.S. Contributions to ITER MIE, FES is placing increasing emphasis on its national burning plasma program—a critical underpinning to the fusion science in ITER. FES plans to enhance burning plasma research efforts across the U.S. domestic fusion program, including the following elements:

- Providing ITER R&D support both in physics and technology and exploring new modes of improved or extended ITER performance;
- Developing safe and environmentally attractive technologies necessary for ITER and longer-term fusion devices;
- Exploring fusion simulation efforts that examine the complex behavior of burning plasmas in tokamaks, which will impact the planning and conduct of experimental operations in ITER;
- Continuing support of our National Compact Stellarator Experiment (NCSX) to keep it on budget and on schedule for completion in FY 2009 to improve our understanding of magnetic confinement of plasma;
- Carrying out experiments on our National Science facilities with diagnostics and plasma control that can be extrapolated to ITER; and
- Integrating all that is learned into a forward-looking approach to future fusion applications.

The activities described above uphold many of the program priorities recommended by the Fusion Energy Sciences Advisory Committee.

Strategic and Program Goals

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

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

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

Program Goal 05.24.00.00: Bring the power of the Stars to Earth — Answer the key scientific questions and overcome enormous technical challenges to harness the power that fuels our sun.

Contribution to Program Goal 05.24.00.00 (World-Class Scientific Research Capacity)

The FES program contributes to this goal by managing a program of fundamental research into the nature of fusion plasmas and the means for confining plasma to yield energy. This includes: 1) exploring basic issues in plasma science; 2) developing the scientific basis and computational tools to predict the behavior of magnetically confined plasmas; 3) using the advances in tokamak research to enable the initiation of the burning plasma physics phase of the Fusion Energy Sciences program; 4) exploring innovative confinement options that offer the potential to increase the scientific understanding of plasmas in various configurations; 5) investigating non-neutral plasma physics and high energy density physics; and 6) developing the cutting edge technologies that enable fusion facilities to achieve their scientific goals.

These activities require operation of a set of unique and diversified experimental facilities, including smaller-scale university devices involving individual Principal Investigators, larger national facilities that require extensive collaboration among domestic institutions and an even larger, more costly experiment that requires international collaborative efforts to share the costs and gather the scientific and engineering talents needed to undertake such an experiment. These facilities provide scientists with the means to test and extend theoretical understanding and computer models—leading ultimately to an improved predictive capability for fusion science.

A major portion of the FES program contribution to this goal is going to be achieved through participation in ITER, an international collaboration to build the first fusion science experiment capable of producing a sustained fusion reaction, called a "burning plasma." A sustained, burning (or self-heated) plasma is the next frontier in fusion science. In September 2002, the Fusion Energy Sciences Advisory Committee (FESAC) concluded that the fusion program is technically and scientifically ready to proceed with a burning plasma experiment and recommended joining the ongoing negotiations to construct the international burning plasma experiment, ITER. The National Research Council of the National Academy of Sciences subsequently endorsed this strategy (Burning Plasma: Bringing a Star to Earth released September 2003). Based in part on these recommendations, plus an Office of Science assessment of the credibility of the cost estimate for the construction of ITER, the President decided in January 2003 that the United States should join the ITER negotiations. This proposed international collaboration will test the scientific and technical feasibility of fusion power. In FY 2003 and FY 2004, the ITER Parties completed much of the international agreement for proceeding with the ITER program and attempted to reach agreement on a construction site in Japan or France. The host candidates, Japan and the European Union, are conducting bilateral discussions in an attempt to resolve the site selection choice.

The FY 2006 Budget provides for the start in mid-FY 2006 of the Major Item of Equipment (MIE) project entitled the "U.S. Contributions to ITER"; this title is chosen to make clear the distinction between the international ITER project, in which the U.S. will be one of many participating parties, and the MIE for which the U.S. has full responsibility. The Total Project Cost, including Total Estimated Cost (TEC) and Other Project Costs (OPC), for the U.S. Contributions to ITER MIE is summarized below in the Significant Program Shifts section and consists of two parts; the Total Estimated Cost is identified in the Facilities Operations subprogram and Other Project Costs are identified in the Enabling R&D subprogram.

The following indicators establish specific long term (10 years) goals in scientific advancement to which the FES program is committed and against which progress can be measured.

- **Predictive Capability for Burning Plasmas:** Progress toward developing a predictive capability for key aspects of burning plasmas using advances in theory and simulation benchmarked against a comprehensive experimental database of stability, transport, wave-particle interaction, and edge effects.
- **Configuration Optimization:** Progress toward demonstrating enhanced fundamental understanding of magnetic confinement and improved basis for future burning plasma experiments through research on magnetic confinement configuration optimization.
- **High Energy Density Plasma Physics:** Progress toward developing the fundamental understanding and predictability of high energy density plasma physics.

Annual Performance Results and Targets

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Program Goal 05.24.00.00 (World-Class Scientific Research Capacity)					
Science					
				Conduct experiments on the major fusion facilities (DIII-D, Alcator C-Mod and NSTX) leading toward the predictive capability for burning plasmas and configuration optimization. **–** In FY 2005, FES will measure plasma behavior in Alcator C-Mod with high-Z antenna guards and input power greater than 3.5 MW.[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 2006, FES will inject 2 MW of neutral power in the counter direction on DIII-D and measure the change in plasma toroidal rotation.
				Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. **–** In FY 2005, FES will simulate nonlinear plasma edge phenomena using extended MHD codes with a resolution of 20 toroidal modes.	Increase resolution in simulations of plasma phenomena—optimizing confinement and predicting the behavior of burning plasmas require improved simulations of edge and core plasma phenomena, as the characteristics of the edge can strongly affect core confinement. **–** In FY 2006, FES will simulate nonlinear plasma edge phenomena using extended MHD codes with a resolution of 40 toroidal modes.

[a] This target addresses issues related to first wall choices and the trade-offs between low-Z and high-Z materials. This choice can affect many important aspects of tokamak operation, including: impurity content and radiation losses from the plasma; hydrogen isotope content in the plasma and retention in the walls; and disruption hardiness of device components. All of these issues are significant when considering choices for next step devices to study burning plasma physics, especially ITER. Definitive experimental results will be compared to model predictions, and will be documented in a *Target Completion Report* in September 2005.

FY 2001 Results	FY 2002 Results	FY 2003 Results	FY 2004 Results	FY 2005 Targets	FY 2006 Targets
Facility Operations					
Kept deviations in weeks of operation for each major facility within 10% of the approved plan. [met goal]	*Kept deviations in weeks of operation for each major facility within 10% of the scheduled weeks. [met goal]*	*Kept deviations in weeks of operation for DIII-D and Alcator C-Mod within 10% of the approved plan. NSTX did not meet the target because of a coil joint failure. [Goal partially met.]*	*Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.[met goal]*	*Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.*	*Average achieved operational time of major national fusion facilities as a percentage of total planned operational time is greater than 90%.*
Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10% of approved baselines; achieved planned cost and schedule performance for dismantling, packaging, and offsite shipping of the Tokamak Fusion Test Reactor (TFTR) systems. [met goal]	*Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10% of project baselines; successfully completed within cost and in a safe manner all TFTR decontamination and decommissioning activities. [met goal]*	*Kept deviations in cost and schedule for upgrades and construction of scientific user facilities within 10% of approved baselines. [met goal]*	*Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%. [met goal]*	*Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.*	*Cost-weighted mean percent variance from established cost and schedule baselines for major construction, upgrade, or equipment procurement projects kept to less than 10%.*

Means and Strategies

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

The science and the technology of fusion have progressed to the point that the next major research step is the exploration of the physics of a sustained plasma reaction in a burning plasma physics experiment. The proposed international burning plasma experiment called ITER is the focal point of sustained burning plasma fusion research around the world, and the Administration has joined the negotiations to conduct this experiment. In light of this action, many elements of the fusion program that are broadly applicable to burning plasmas are now being directed more specifically toward the needs of ITER. These elements represent areas of fusion research in which the United States has particular strengths relative to the rest of the world, such as theory, modeling, and tokamak experimental physics. Longer range technology activities have been phased out or redirected to support preparations for the realization of the burning plasma device and associated experiments.

Scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad and conduct comparative studies to supplement the scientific understanding obtained from domestic facilities. These include the world's highest performance tokamaks (JET in England and JT-60 in Japan), a stellarator (the Large Helical Device in Japan), a superconducting tokamak (Tore Supra in France), and several smaller devices. In addition, the United States is collaborating with South Korea on the design of diagnostics for the long-pulse, superconducting, advanced tokamak (KSTAR). The strengthened relationships resulting from these international collaborations can foster scientific advancement and facilitate shared science worldwide. These collaborations provide a valuable link with the 80% of the world's fusion research that is conducted outside the United States. The United States is an active participant in the International Tokamak Physics Activity (ITPA), which facilitates identification of high priority research for burning plasmas in general, and for ITER specifically, through workshops and assigned tasks. ITPA further identifies coordinated experiments on the international tokamak programs and coordinates implementation of these experiments through the International Energy Agency Implementing Agreements on tokamaks. In FY 2004, the United States began participating in the ITER Transitional Arrangements activities which are preparations for the international project and the U.S. component fabrication for ITER. The FY 2006 request for ITER continues these preparations until mid-FY 2006 when the ITER MIE TEC and OPC are scheduled to begin. For the latter half of FY 2006, TEC funds are identified for the U.S. Contributions to ITER MIE in the Facility Operations subprogram. Certain funds within the Enabling R&D subprogram are redirected in the latter half of FY 2006 to Other Project Cost activities, focused on directly-related, specific R&D needed to support the procurements in the U.S Contributions to ITER MIE. These funds are needed for R&D and design in support of equipment—mainly heating, current drive and diagnostics—that will be provided by the U.S. to ITER. The results of this R&D and design are broadly applicable to future burning plasma experiments. In addition, there is related support for both the ITER physics basis and the preparations for science and technology research to be conducted using ITER. This related support comes from a broad spectrum of science and technology activities within the FES program such as the experimental research from existing facilities, as well as the fusion plasma theory and computation activities, and is not part of the MIE TEC or TPC.

All research projects undergo regular peer review and merit evaluation based on SC-wide procedures and Federal regulations pertaining to extramural grant programs under 10 CFR 605. A similar and modified process is also followed for research proposals submitted by the laboratory programs and national collaborative facilities. All new projects are selected by peer review and merit evaluation. FES formally peer reviews the FES scientific facilities to assess the scientific output, collaborator satisfaction, the overall cost-effectiveness of each facility's operations, and the ability to deliver the most advanced scientific capability to the fusion community. Major facilities are reviewed by an independent peer process on a 5-year basis as part of the grant renewal process, or an analogous process for national laboratories. Checkpoint reviews at the 3-year point provide interim assessment of program quality. Program Advisory Committees for the major facilities provide annual or semi-annual feedback on assessments of the quality of research performed at the facility; the reliability and availability of the facility; user access policies and procedures; collaborator satisfaction; facility staffing levels; R&D activities to advance the facility; management of the facility; and long-range goals of the facility.

Facility upgrades and construction projects have a goal to stay within 10 percent, on average, of cost and schedule baselines for upgrades and fabrication of scientific facilities. In FES, fabrication of major research facilities has generally been on time and within budget. Major collaborative facilities have a goal to operate more than 90 percent, on average, of total planned annual operating time. FES's operation of major scientific facilities has ensured that a growing number of U.S. scientists have reliable access to those important facilities.

External factors that affect the level of performance include:

(1) changing mission needs as described by the DOE and SC mission statements and strategic plans;
(2) scientific opportunities as determined, in part, by proposal pressure and scientific workshops;
(3) results of external program reviews and international benchmarking activities of entire fields or sub fields, such as those performed by the National Academy of Sciences (NAS);
(4) unanticipated failures in critical components of scientific facilities that cannot be mitigated in a timely manner; and
(5) strategic and programmatic decisions made by non-SC funded domestic research activities and by major international research centers.

Validation and Verification

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

Program Assessment Rating Tool (PART) Assessment

The Department implemented a tool, the PART Assessment, to evaluate selected programs. PART was developed by OMB to provide a standardized way to assess the effectiveness of the Federal Government's portfolio of programs. The structured framework of the PART provides a means through which programs can assess their activities differently than through traditional reviews. The Fusion Energy Sciences (FES) program has incorporated feedback from OMB into the FY 2005 and FY 2006 Budget Requests and has taken the necessary steps to continue to improve performance.

In the FY 2005 PART review, OMB gave the FES program a relatively high score of 82% overall which corresponds to a rating of "Moderately Effective." This score is attributable to the use of standard management practices in FES. The assessment found that FES has developed a limited number of adequate performance measures which are continued for FY 2006. These measures have been incorporated into this Budget Request, FES grant solicitations and the performance plans of senior managers. As appropriate, they will be incorporated into the performance based contracts of M&O contractors. To explain these complex scientific measures better, the Office of Science has developed a website (http://www.sc.doe.gov/measures/) that answers questions such as "What does this measure mean?" and "Why is it important?" Roadmaps, developed in consultation with the Fusion Energy

Sciences Advisory Committee (FESAC) and also available on the website, will guide reviews, every three years by FESAC, of progress toward achieving the long-term Performance Measures. The Annual Performance Targets are tracked through the Department's Joule system and reported in the Department's Annual Performance Report. In response to PART findings, FES established a Committee of Visitors (COV) process to provide outside expert validation of the program's merit-based review processes for impact on quality, relevance, and performance. The first COV report is available on the web (http://www.ofes.fusion.doe.gov/More_HTML/FESAC/CommitteeOfVisitors.pdf). FES developed an action plan to respond to the findings and recommendations of the COV within 60 days of receiving the report. This action plan is also available on the web at (http://www.ofes.fusion.doe.gov/More_HTML/FESAC/COVLettertoHazeltine.pdf).

OMB found that the FES budget was not sufficiently aligned with scientific program goals and that a science-based strategic plan for the future of U.S. fusion research within an international context needs to be developed. In response, FESAC has been tasked to write a report that identifies and prioritizes scientific issues and respective campaign strategies. An interim report was completed in July 2004 and a final report is expected in FY 2005. This report will form the basis of an FES strategic plan which will also include efforts in ITER. Completion of this plan is targeted for September 2005.

Funding by General and Program Goal

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Goal 5, World-Class Scientific Research Capacity			
Program Goal 05.24.00.00, Bring the Power of the Stars to Earth			
Science	142,723	155,063	142,771
Facility Operations: Non-ITER	82,535	84,996	75,519
Facility Operations: ITER Preparations	3,155	4,947	6,000
ITER MIE TEC	0	0	46,000
Enabling R&D: Non-ITER	27,446	28,897	16,760
Enabling R&D: ITER MIE OPC	0	0	3,500
Total, General Goal 5, World-Class Scientific Research Capacity	255,859	273,903	290,550

Overview

Fusion science is a subfield of plasma science that deals primarily with the study of fundamental processes taking place in plasmas, or ionized gases, in which the temperature and density approach the conditions needed to allow the nuclei of two low-mass elements, e.g., hydrogen isotopes deuterium and tritium, to join together, or fuse. When these nuclei fuse, a large amount of energy is released. There are two leading methods of confining the fusion plasma—magnetic confinement, in which strong magnetic fields constrain the charged plasma particles, and inertial confinement, in which laser or particle beams or x-rays (drivers) compress and heat the plasma (target) during very short pulses. Most of the world's fusion energy research effort, the United States included, is focused on the magnetic confinement approach. However, the National Nuclear Security Administration (NNSA) supports a robust program in inertial fusion for stockpile stewardship. By leveraging this large NNSA investment, FES is able to access an important research base from which the physics of the target-driver interaction can be studied in the hopes of finding a promising path to practical fusion energy.

The Fusion Energy Sciences program activities are designed to address the scientific and technology issues facing fusion:

- The transport of plasma heat from the core of the plasma outward to the plasma edge and to the material walls as a result of electromagnetic turbulence in the plasma;
- The stability of magnetic configuration and its variation in time as the plasma pressure, density, turbulence level, and population of high energy fusion products change;
- The role of the colder plasma at the plasma edge and its interaction with both material walls and the hot plasma core;
- The interaction of electrons and ions in the plasma with high-power electromagnetic waves injected into the plasma for plasma heating, current drive and control; and
- The development of reliable and economical superconducting magnets, plasma heating and fueling systems, vacuum chamber, and heat extraction systems and materials that can perform satisfactorily in an environment of fusion plasmas and high energy neutrons.

These issues have been codified into four thrusts that characterize the program activities:

- Burning Plasmas, that will include our efforts in support of ITER;
- Fundamental Understanding, that includes high performance plasma experiments, theory and modeling, as well as general plasma science;
- Configuration Optimization, that includes innovative experiments on advanced tokamaks, and alternate concepts;
- Materials, Components and Technologies that include enabling technologies and fusion-specific materials science (closely coupled to the Basic Energy Sciences (BES) materials science program).

Progress in all of these thrust areas, in an integrated fashion, is required to achieve ultimate success.

How We Work

The primary role of FES is management of resources and technical oversight of the program. FES has established an open process for obtaining scientific input for major decisions, such as the planning, funding, evaluating and, where necessary, terminating facilities, projects, and research efforts. There are also mechanisms in place for building fusion community consensus and orchestrating mutually beneficial international collaborations that are fully integrated with the domestic program. FES is likewise active in promoting effective outreach to and communication with related scientific and technical communities, industrial and government stakeholders, and the public.

Advisory and Consultative Activities

The Department of Energy uses a variety of external advisory entities to provide input that is used in making informed decisions on programmatic priorities and allocation of resources. The FESAC is a standing committee that provides independent advice to the Director of the Office of Science on complex scientific and technological issues that arise in the planning, implementation, and management of the fusion energy sciences program. The Committee members are drawn from universities, national laboratories, and private firms involved in fusion research or related fields. The Director of the Office of Science charges the Committee to provide advice and recommendations on various issues of concern to the fusion energy sciences program. The Committee conducts its business in public meetings, and submits reports with advice and recommendations to the Department.

A variety of other committees and groups provide input to program planning. Ad hoc activities by fusion researchers provide a forum for community debate and formation of consensus. The President's Committee of Advisors on Science and Technology (PCAST) has also examined the fusion program on several occasions, as has the Secretary of Energy Advisory Board. The National Research Council, whose Plasma Physics Committee serves as a continuing connection to the general plasma physics community, recently carried out an assessment of the Department of Energy's Fusion Energy Sciences' strategy for addressing the physics of burning plasmas. In addition, the extensive international collaborations carried out by U.S. fusion researchers provide informal feedback regarding the U.S. program and its role in the international fusion effort. These sources of information and advice are integrated with peer reviews of research proposals and, when combined with high-level program reviews and assessments, provide the basis for prioritizing program directions and allocations of funding.

Program Advisory Committees (PACs) serve an extremely important role in providing guidance to facility directors in the form of program review and advice regarding allocation of facility run-time. These PACs are comprised primarily of researchers from outside the host facility, including non-U.S. members. They review proposals for research to be carried out on the facility and assess support requirements, and in conjunction with host research committees, provide peer recommendations regarding priority assignments of facility time. Because of the extensive involvement of researchers from outside the host institutions, PACs are also useful in assisting coordination of overall research programs. Interactions among PACs for major facilities assure that complementary experiments are appropriately scheduled and planned.

Facility Operations Reviews

FES program managers perform quarterly reviews of the progress in operating the major fusion facilities. In addition, a review of each of these major facilities occurs periodically by peers from the other facilities. Further, quarterly reviews of each major project are conducted by the Associate Director for Fusion Energy Sciences with the Federal Project Director in the field and other involved staff from both the Department and the performers.

Program Reviews

The peer review process is used as the primary mechanism for evaluating proposals, assessing progress and quality of work, and for initiating and terminating facilities, projects, and research programs. This policy applies to all university and industry programs funded through grants, national laboratory programs funded through Field Work Proposals (FWPs), and contracts from other performers. Peer review guidelines for FES derive from best practices of government organizations that fund science and technology research and development, such as those documented in the General Accounting Office report, "Federal Research: Peer Review Practices at Federal Science Agencies Vary" (GAO/RCED-99-99, March 1999), as well as more specifically from relevant peer review practices of other programs in the Office of Science.

Merit review in FES is based on peer evaluation of proposals and performance in a formal process using specific criteria and the review and advice of qualified peers. In addition to the review of the scientific quality of the programs provided by the peer review process, FES also reviews the proposals for their balance, relevance, and standing in the broader scientific community.

Universities and most industries submit grant proposals to receive funding from FES for their proposed work. Grants typically extend for a three- to five-year period. The grants review process is governed by the already established SC Merit Review System. DOE national laboratories submit annual FWPs for funding of both new and ongoing activities. These are subject to peer review according to procedures patterned after those in 10 CFR Part 605, which governs the SC grant program. For the major facilities that FES funds, these extensive reviews are conducted as part of a contract or cooperative agreement renewal, with nominal five-year renewal dates. External peer reviews of laboratory programs are carried out on a periodic basis.

Another review mechanism, motivated in response to PART findings, involves charging FESAC to establish a Committee of Visitors (COV) to review program management practices every three to four years on a rotating basis for the following program elements: theory and computation, confinement innovations, general plasma sciences, tokamak research, and enabling research and development. In March 2004, a COV completed its review of the research portfolio and peer review process for the FES theory and computation program. It concluded that this FES-supported research program was of very high quality. Further, the COV was impressed with both the success of the FES and its implementation of a comparative peer review, which had improved significantly over the last three years, and with the quality of the reviewers chosen by the FES theory team.

Planning and Priority Setting

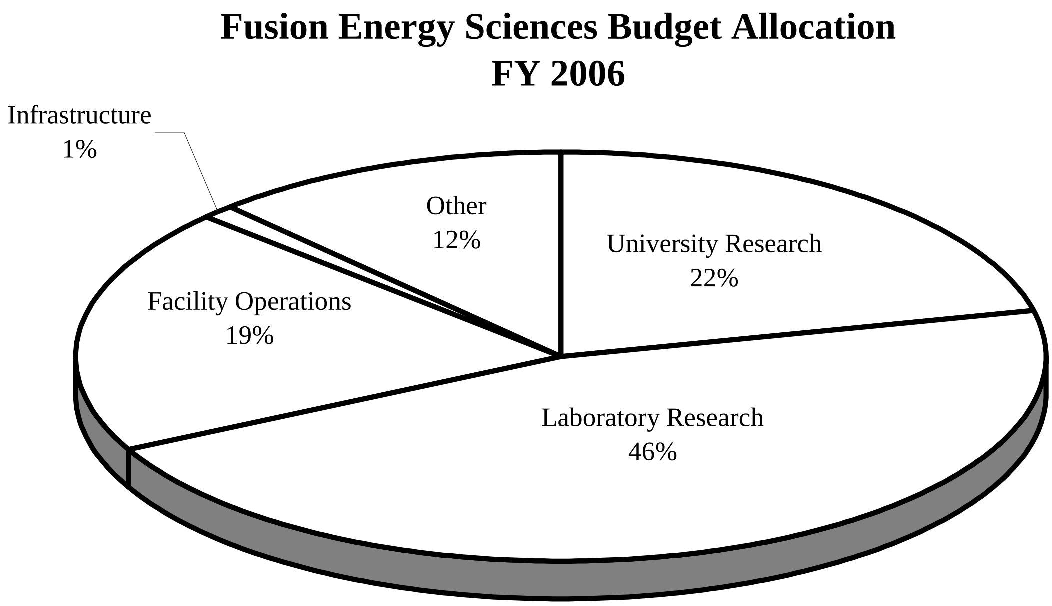
The FESAC carries out an invaluable role in the fusion program by identifying critical scientific issues and providing advice on intermediate and long-term goals to address these issues. Currently, FESAC is assisting the Department and the fusion community in establishing priorities for the fusion program, including strategies to integrate U.S. activities in ITER into the overall U.S. domestic fusion program. FESAC's objectives will include a prioritized balancing of the content, scope, and level of U.S. activities in fusion. Their efforts will aim to 1) identify major program issues in science and technology that need to be addressed, 2) recommend how to organize campaigns to address those issues, and 3) recommend the order of priority in which these campaigns will be pursued. FESAC's report on this activity is expected to be completed in fiscal year 2005.

A variety of sources of information and advice, as noted above, are integrated with peer reviews of research proposals. These, combined with high-level program reviews and assessments, provide the basis for prioritizing program directions and allocations of funding.

How We Spend Our Budget

The FES budget has three components: Science, Facility Operations, and Enabling R&D. Research efforts are distributed across universities, laboratories, and private sector institutions. In addition to a major research facility at Massachusetts Institute of Technology (MIT), there are several smaller experimental facilities located at universities. There are two other major facilities, located at a national laboratory (Princeton Plasma Physics Laboratory), and a private sector institution (General Atomics [GA]). Technology supports and improves the technical capabilities for ongoing experiments and provides limited long-term development for future fusion power requirements.

The balance of funding levels and priorities are reviewed by the FESAC. The following chart illustrates the allocation of funding to the major program elements.



Research

The DOE Fusion Energy Sciences program funds research activities involving over 1,100 researchers and students at 65 academic and private sector institutions located in 30 states and at 11 DOE and Federal laboratories in 8 states. The three major facilities are operated by the hosting institutions but are configured with national research teams made up of local scientists and engineers, and researchers from other institutions and universities, as well as foreign collaborators.

- **University Research**

  University researchers continue to be a critically important component of the fusion research program and are responsible for training graduate students. University research is carried out on the full range of scientific and technical topics of importance to fusion. University researchers are active participants on the major fusion facilities and one of the major facilities is sited at a university (Alcator C-Mod at MIT). In addition, there are 16 smaller research and technology facilities located at universities, including a basic plasma science user facility at University of California, Los Angeles (UCLA) that is jointly funded by DOE and NSF. There are 5 universities with significant groups of theorists and modelers. About 40 Ph.D. degrees in fusion-related plasma science and engineering are awarded each year. Over the past three decades, many of these graduates have gone into the industrial sector and brought with them the technical basis for many of the plasma applications found in industry today, including the plasma processing on which today's semiconductor fabrication lines are based.

  The university grants program is proposal driven. External scientific peer review proposals submitted in response to announcements of opportunity and available funding are competitively awarded according to the guidelines published in 10 CFR Part 605. Support for basic plasma physics is carried out through the NSF/DOE Partnership in Basic Plasma Science and Engineering.

  In addition, the FES Principal Young Investigator program supports tenure track university faculty on a competitive basis; research in fusion and plasma science is included in this program.

- **National Laboratory and Private Sector Research**

  FES supports national laboratory-based fusion research groups at the Princeton Plasma Physics Laboratory, Oak Ridge National Laboratory, Sandia National Laboratory, Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, Idaho National Engineering and Environmental Laboratory, Argonne National Laboratory, Pacific Northwest National Laboratory, and Los Alamos National Laboratory. In addition, one of the major research facilities is located at and operated by General Atomics in San Diego, California. The laboratory programs are driven by the needs of the Department, and research and development carried out there is tailored to take specific advantage of the facilities and broadly based capabilities found at the laboratories.

  Laboratories submit FWPs for continuation of ongoing or new work. Selected parts of proposals for continuing work are reviewed on a periodic basis, and proposals for new work are peer reviewed. FES program managers review laboratory performance on a yearly basis to examine the quality of their research and to identify needed changes, corrective actions, or redirection of effort.

Significant Program Shifts

The FY 2006 request is $290,550,000, an increase of $16,647,000, 6.1% over the FY 2005 Appropriation. The FY 2006 budget continues the redirection of the fusion program to prepare for and participate in the ITER project.

Operation of the three major fusion research facilities will be reduced from a total of 48 weeks to 17 weeks. There will be a net decrease of approximately 150 scientists, engineers, and supporting staff from the program. The largest reductions will be mainly at ORNL, PPPL, General Atomics, LBNL, and LLNL; however, the reductions will affect other fusion program participants as well.

Within the overall priorities of the FY 2006 FES budget, $15,900,000 is requested for the National Compact Stellarator Experiment (NCSX), a joint ORNL/PPPL advanced stellarator experiment being built at PPPL. The FY 2006 request is $1,600,000 less than FY 2005, and the schedule for completion is extended to May 2009 with an estimated TEC of $90,839,000. A new cost and schedule performance baseline consistent with the FY 2006 request and expected outyears will be developed in the mid-FY 2005 timeframe.

Other program shifts include a reduction of $7,255,000 from the FY 2005 level in the Inertial Fusion Energy/High Energy Density Physics program. This will be accomplished by reducing the level of research on heavy ion beams at Lawrence Berkeley National Laboratory, the Lawrence Livermore National Laboratory, the Princeton Plasma Physics Laboratory and the associated universities supporting the heavy ion beams research. Within the reduced funding level, this program element will concentrate on the use of ion beams for high energy density physics research, and other innovative approaches to high energy density physics, including Fast Ignition, as recommended by the national Task Force on High Energy Density Physics commissioned by the Office of Science and Technology Interagency Working Group on the Physics of the Universe. In addition, the Materials Research program will be eliminated in favor of reliance upon the general BES materials effort for scientific advances in areas of fusion interest.

ITER

Multilateral ITER negotiations continued in FY 2004 and into FY 2005. In collaboration with the ITER parties, a comprehensive process to prepare the written ITER Agreement covering all phases of the ITER project has been put in place. This includes incorporation of input on all topics by topical experts from each negotiating party, discussion by representatives of each party and resolution of differences by the negotiators. A negotiated agreement is expected to be completed in FY 2005 for consideration and approval within the parties' governmental systems. In addition, representatives of the parties addressed critical implementation decisions on detailed arrangements including assignment of management personnel. As part of the continuing preparations for the international ITER project, DOE selected PPPL in partnership with ORNL to manage the U.S. ITER Project Office based upon a competitive selection process involving all the DOE fusion laboratories. This office is responsible for U.S. ITER preparations and the provision of U.S. contributions to ITER, including hardware, personnel and cash for the U.S. share of common costs at the ITER site such as installation and testing.

The FY 2006 request for the U.S. Contributions to ITER MIE includes Total Estimated Cost (TEC) funding of $46,000,000 in the Facilities Operations subprogram and Other Project Cost (OPC) funding of $3,500,000, redirected within the Enabling R&D subprogram. The TEC and OPC funding for FY 2006 through FY 2013 are reflected below.

The ITER International Agreement is currently being negotiated and is expected to be completed by the end of FY 2005. The Agreement will finalize the current provisional list of equipment to be provided by each ITER Party and will finalize the mode of operation among the ITER Parties and central project team during the construction, operation and decommissioning phases of the ITER program. The following MIE project cost estimates for U.S. Contributions to ITER are preliminary until the Agreement is completed, following which the baseline scope, cost and schedule for the MIE project will be established.

U.S. Contributions to ITER
Annual Profile

(budget authority in thousands)

Fiscal Year	Total Estimated Costs	Other Project Costs	Total Project Costs[a]
2006	46,000	3,500	49,500
2007	130,000	16,000	146,000
2008	182,000	18,800	200,800
2009	191,000	16,500	207,500
2010	189,000	10,300	199,300
2011	151,000	9,300	160,300
2012	120,000	6,200	126,200
2013	29,000	3,400	32,400
Total	1,038,000	84,000	1,122,000

[a] Discussions are proceeding on whether ITER Preparation costs should also be accounted for within the ITER TPC. A determination will be part of the Critical Decision – 1 process.

Estimated TEC, OPC and TPC Costs

	(dollars in thousands)	
	Current Estimate	Previous Estimate
Fabrication Costs		
Procurement of U.S. in-kind equipment (~10% of ITER need)	573,800	n/a
Installation of U.S. in-kind equipment	71,900	n/a
Assignment of U.S. scientists and engineers to ITER Org (~10% of ITER need)	87,300	n/a
Contribution of funds for support personnel at ITER Org (~10% of ITER need)	36,200	n/a
Operation of U.S. ITER Project Office including management, QA, procurement, etc.	123,600	n/a
Subtotal	892,800	n/a
Contingencies at approximately 16% of above costs	145,200	n/a
Total Estimated Costs (TEC)	1,038,000	n/a
Other Project Costs - Base Program R&D and Design Support for above tasks	68,000	n/a
Contingencies at approximately 24% of OPC costs	16,000	n/a
Total Other Project Costs (OPC)	84,000	n/a
Total Project Costs (TPC)	1,122,000	n/a

Related Annual Funding Requirements

	(dollars in thousands)	
	Current Estimate	Previous Estimate
FY 2014 - FY 2033		
U.S. share of annual facility operating costs including commissioning, maintenance, repair, utilities, power, fuel, improvements and annual contribution to decommissioning fund for period 2014 to 2033. Estimate is in year 2014 dollars.	58,300	n/a
FY 2034 – FY 2038		
U.S. share of the annual cost of deactivation of ITER facility for period 2034 – 2038. Estimate is in year 2036 dollars.	17,000	n/a

FY 2006 funding of $49,500,000 is for the startup of the U.S. Contributions to ITER MIE. The total U.S. Contributions to ITER MIE, $1,122,000,000, consists of both the TEC funding for the fabrication of the equipment, provision of personnel, and limited cash for the U.S. share of common project expenses at the ITER site, as well as the OPC funding for activities supporting the TEC-funded procurements. This MIE is augmented by the technical output from a significant portion of the U.S. Fusion Energy Sciences community research program. The U.S. is a major participant in the International Tokamak Physics Activity (ITPA), which delineates high priority physics needs for ITER and assists their implementation through collaborative experiments among the major international tokamaks, and analysis and interpretation of experiments for extrapolation to ITER. Virtually the entire FES program provides related contributions to such ITER relevant research, not part of the TEC, OPC and TPC, and prepares the U.S. for effective participation in ITER when it starts operations.

The specific annual funding levels for TEC and OPC are subject to change when the performance baseline for scope, cost, and schedule of the U.S. project is established (defined as Critical Decision 2 under DOE Order 413.3). With the exception of possible changes in OMB-established inflation rates, and currency exchange rates affecting about 15% of the TPC funding, the overall TPC for the U.S. Contributions to ITER MIE will remain $1,122,000,000 when the performance baseline is established. The estimated timeframe for establishing the performance baseline is within the first or second quarter of FY 2006, and by this time the ITER Director General and key staff are expected to be in place.

The TEC funds for the U.S. Contributions to ITER MIE provide for the U.S. share, about 10%, of the international ITER project construction cost. The U.S. share includes fabrication of equipment, assignment of personnel to the ITER project organization and cash for equipment installation and common expenses. TEC funds are needed starting in mid-FY 2006 based on an FY 2005 ITER site selection and an FY 2006 start of the international project. These funds are budgeted within the Facility Operations subprogram.

The OPC funds for the U.S. Contributions to ITER MIE support R&D and design activities focused on ITER and also are broadly applicable to the overall burning plasma program. MIE OPC funds are also needed starting in mid-FY 2006. These OPC funds are budgeted within the Enabling R&D subprogram.

FY 2004 Awards

- A fusion scientist at Princeton University received an E.O. Lawrence Award in the nuclear technology category for his discovery of ways to use plasma waves to produce currents in tokamaks.
- A research physicist on the National Spherical Torus Experiment (NSTX) won the United States Presidential Department of Energy Early Career Award for his studies on how to achieve optimum stability in high performance plasmas in a very compact tokamak, which impact the design and physics basis for NSTX and future spherical torus (ST) reactors.
- A fusion materials scientist has been elected as General Chairman of the “Second International Conference on Multiscale Modeling of Materials,” the largest worldwide activity in Computational Materials Science.
- A member of the DOE-funded Plasma Science Fusion Center was named Head of the MIT Department of Nuclear Engineering.
- The University of Milan conferred an honorary doctorate upon an eminent fusion scientist. A Symposium on “Plasmas in the Universe” was held in his honor in connection with the award.
- A fusion scientist at the University of Wisconsin received the 2004 James Clerk Maxwell Prize for Plasma Physics
- Five fusion scientists received the American Physical Award for Excellence in Plasma Physics Research.
- Ten fusion scientists were made Fellows of the American Physical Society.
- Two fusion scientists were named Fellows of the American Association for the Advancement of Science.

Scientific Discovery through Advanced Computing (SciDAC)

The Scientific Discovery through Advanced Computing (SciDAC) program is a set of coordinated investments across all Office of Science mission areas with the goal of achieving breakthrough scientific advances through computer simulation that are impossible using theoretical or laboratory studies alone.

The power of computers and networks is increasing exponentially. By exploiting advances in computing and information technologies as tools for discovery, SciDAC encourages and enables a new model of multi-discipline collaboration among the scientific disciplines, computer scientists, and mathematicians. The product of this collaborative approach is a new generation of scientific simulation codes that can fully exploit terascale computing and networking resources. The program will bring simulation to a parity level with experiment and theory in the scientific research enterprise as demonstrated by major advances in climate prediction, plasma physics, particle physics, and astrophysics.

During the past year, multidisciplinary teams of computational plasma physicists, applied mathematicians, and computer scientists have completed three-year research projects in the areas of magnetic reconnection, macroscopic stability, electromagnetic wave-plasma interaction, simulation of turbulent transport of energy and particles, and atomic physics relevant to edge plasma physics. These teams achieved significant advances in the simulation of mode conversion of radio frequency waves in tokamak plasmas, modeling of the sawtooth instability in tokamaks with realistic plasma parameters, and understanding turbulent transport as a function of plasma size in tokamaks. The fusion SciDAC projects were completed in FY 2004, and a new round of three-year SciDAC awards was initiated in the 4th quarter of 2004. These newly funded projects are focused on the topics of microturbulence simulation, extended MHD modeling, and simulation of electromagnetic wave-plasma interaction. In 2005, the Fusion Energy Sciences program and the Advanced Scientific Computing Research program will fund one or two prototype focused integration initiatives, based on a competitive peer review process.

Scientific Facilities Utilization

The Fusion Energy Sciences request includes funds to operate and use major fusion physics collaborative science facilities. The Department's three major fusion physics facilities are: the DIII-D Tokamak at General Atomics in San Diego, California; the Alcator C-Mod Tokamak at the Massachusetts Institute of Technology; and the National Spherical Torus Experiment (NSTX) at the Princeton Plasma Physics Laboratory. These three facilities are each unique in the world's fusion program and offer opportunities to address specific fusion science issues that will contribute to the expanding knowledge base of fusion. Taken together, these facilities represent nearly $1,000,000,000 of capital investment by the U.S. Government, in current year dollars.

The funding requested will provide research time for about 230 scientists in universities, federally sponsored laboratories, and industry, and will leverage both federally and internationally sponsored research, consistent with a strategy for enhancing the U.S. national science investment.

The total number of hours of operation at all of the major fusion facilities is shown in the following table.

	FY 2004	FY 2005	FY 2006
Optimal hours	3,000	3,000	3,000
Planned hours	2,320	1,920	680
Hours operated as percent of planned hours	100%	TBD	TBD

In addition to the operation of the major fusion facilities, the NCSX MIE project at PPPL is supported in the fusion program. Milestones for this project are shown in the following table.

FY 2004	FY 2005	FY 2006
Completed final design of NCSX and began fabrication.	Award, through a competitive process, production contracts for the NCSX modular coil winding forms and conductor and vacuum vessel. Complete winding of the first modular coil.	Complete fabrication of vacuum vessel subassemblies and one-third of the modular coil winding forms.

Workforce Development

The FES program, the Nation's primary sponsor of research in plasma physics and fusion science, supports development of the R&D workforce by funding undergraduate researchers, graduate students working toward masters and doctoral degrees, and postdoctoral associates developing their research and management skills. The R&D workforce developed as a part of this program provides new scientific talent to areas of fundamental research. It also provides talented people to a wide variety of technical and industrial fields that require finely honed thinking and problem solving abilities and computing and technical skills. Scientists trained through association with the FES program are employed in related fields such as plasma processing, space plasma physics, plasma electronics, and accelerator/beam physics as well as in other fields as diverse as biotechnology and investment and finance.

In FY 2004, the FES program supported 435 graduate students and post-doctoral investigators. Of these, approximately 40 students conducted research at the DIII-D tokamak at General Atomics, the Alcator C-Mod tokamak at MIT, and the NSTX at PPPL. A Junior Faculty development program for university plasma physics researchers and the NSF/DOE partnership in basic plasma physics and engineering focus on the academic community and student education.

Data on the workforce for the FES program are shown in the table below.

	FY 2004	FY 2005 est.	FY 2006 est.
# University Grants	208	223	200
# Permanent PhD's (FTEs)[a]	722	732	669
# Postdoctoral Associates (FTEs)	126	128	121
# Graduate Students (FTEs)	264	264	254
# PhD's awarded	45	45	45

[a] Permanent PhD's includes faculty, research physicists at universities, and all PhD-level staff at national laboratories.

Science

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Science					
Tokamak Experimental Research	44,842	45,147	43,765	-1,382	-3.1%
Alternative Concept Experimental Research	57,319	60,874	49,940	-10,934	-18.0%
Theory	25,367	25,460	24,640	-820	-3.2%
SciDAC	3,319	4,275	4,275	0	--
General Plasma Science	11,876	12,341	13,900	+1,559	+12.6%
SBIR/STTR	0	6,966	6,251	-715	-10.3%
Total, Science	142,723	155,063	142,771	-12,292	-7.9%

Description

The Science subprogram fosters fundamental research in plasma science aimed at a predictive understanding of plasmas in a broad range of plasma confinement configurations. There are two basic approaches to confining a fusion plasma and insulating it from its much colder surroundings—magnetic and inertial confinement. In the former, carefully engineered magnetic fields isolate the plasma from the walls of the surrounding vacuum chamber; while in the latter, a pellet of fusion fuel is compressed and heated so quickly that there is no time for the heat to escape. The Science subprogram supports exploratory research to combine the favorable features of, and the knowledge gained from, magnetic confinement, both for steady-state and pulsed approaches, in new, innovative fusion concepts. There has been great progress in plasma science during the past three decades, in both magnetic and inertial confinement, and today the world is at the threshold of a major advance in fusion energy development—the study of burning plasmas, in which the self-heating from fusion reactions dominates the plasma behavior.

Benefits

The Science subprogram provides the fundamental understanding of plasma science needed to address and resolve critical scientific issues related to fusion burning plasmas. The Science subprogram also explores and develops diagnostic techniques and innovative concepts that optimize and improve our approach to creating fusion burning plasmas, thereby seeking to minimize the programmatic risks and costs in the development of a fusion energy source. Finally, this subprogram provides training for graduate students and post docs, thus developing the national workforce needed to advance plasma and fusion science.

Supporting Information

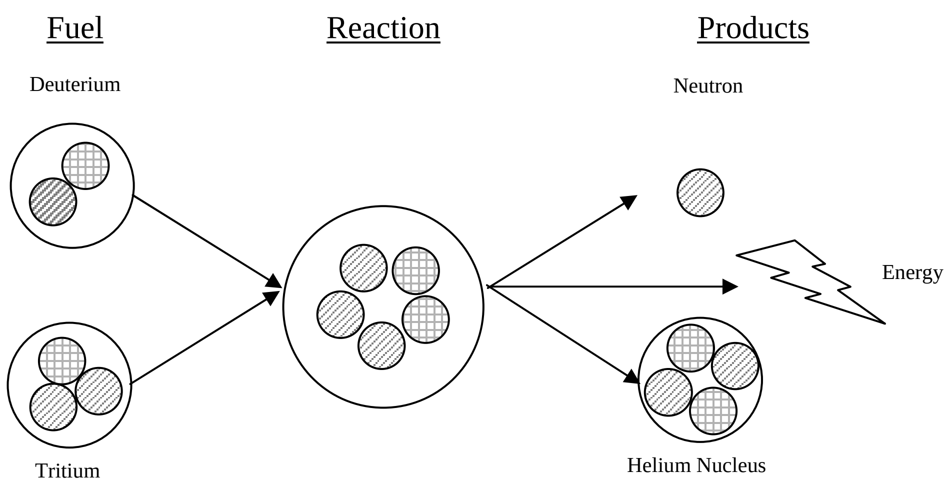
Plasmas, the fourth state of matter, comprise over 99% of the visible universe and are rich in complex, collective phenomena. During the past decade there has been considerable progress in our fundamental understanding of key individual phenomena in fusion plasmas, such as transport driven by micro-turbulence, and macroscopic equilibrium and stability of magnetically confined plasmas. Over the next ten years the Science subprogram will continue to advance our understanding of plasmas through an integrated program of experiments, theory, and simulation as outlined in the Integrated Program Planning Activity for the Fusion Energy Sciences Program prepared for FES and reviewed by the

FESAC. This integrated research program will focus on well-defined plasma scientific issues including turbulence, transport, macroscopic stability, wave particle interactions, multiphase interfaces, hydrodynamic stability, implosion dynamics, fast ignition, and heavy-ion beam transport and focusing. We expect this research program to yield new methods for sustaining and controlling high temperature, high-density plasmas, which will have a major impact on a burning plasma experiment, such as ITER. This integrated research program also will benefit from ignition experiments performed at the NNSA-sponsored National Ignition Facility (NIF).

An additional objective of the Science subprogram is to broaden the intellectual and institutional base in fundamental plasma science. Two activities, an NSF/DOE partnership in plasma physics and engineering, and the Junior Faculty development grants for members of university plasma physics faculties, will continue to contribute to this objective. An ongoing “Centers of Excellence in Fusion Science” program will also foster fundamental understanding and connections to related sciences.

Plasma science includes not only plasma physics but also physical phenomena in a much wider class of ionized matter, in which atomic, molecular, radioactive transport, excitation, and ionization processes are important. These phenomena can play significant roles in partially ionized media and in the interaction of plasmas with material walls. Plasma science contributes not only to fusion research, but also to many other fields of science and technology, such as industrial processing, national security, space propulsion, and astrophysics.

Fusion science, a major sub-field of plasma science, is focused primarily on describing the fundamental processes taking place in plasmas, or ionized gases, in which peak temperatures are greater than 100 million degrees Celsius, and densities are high enough that light nuclei collide and fuse together, releasing energy and producing heavier nuclei. The reaction most readily achieved in laboratory plasmas is the fusion of deuterium and tritium, which produce helium and a neutron.



The Fusion Process

Fusion science shares many scientific issues with plasma science. For Magnetic Fusion Energy (MFE), these include: (1) chaos, turbulence, and transport; (2) stability, magnetic reconnection, self-organization, and dynamos; (3) wave-particle interaction and plasma heating; and (4) sheaths and boundary layers. Progress in all of these fields is likely to be required for ultimate success in achieving a practical fusion source.

For Inertial Fusion Energy (IFE), the two major science issues are: (1) high energy density physics that describes intense laser-plasma and beam-plasma interactions; and (2) non-neutral plasmas, as is seen in the formation, transport, and focusing of intense heavy ion beams.

FY 2004 Science Accomplishments

Research funded by the Fusion Energy Sciences program in FY 2004 is focused on developing a predictive understanding of burning plasmas, finding improved magnetic confinement configurations, and exploring high energy density physics relevant to inertial fusion energy. The U.S. decision to join the ITER negotiations has energized the research in tokamaks, enhancing collaborations among the international tokamak programs and encouraging closer collaborations between theory and experiments. Substantial effort is being put into computer simulations to enhance tools for predictive capability for ITER. The experimental research and the theory and simulations on advanced tokamaks contribute both to the predictive understanding of burning plasmas and to configuration optimization.

Jointly funded by FES and Advanced Scientific Computing Research (ASCR), the National Fusion Collaboratory is developing an infrastructure to enable scientific collaboration for all aspects of magnetic fusion energy research. This effort includes creating a robust, user-friendly collaborative software environment and deploying this to the more than 1,000 scientists in 40 institutions who perform magnetic fusion research in the United States and abroad. The ultimate goal of this collaborative software environment (referred to as the National Fusion Grid) is to allow scientists at remote sites to participate as fully in experiments and computational activities as if they were working at a common site, thus creating a virtual organization of the U.S. fusion community. The main data repositories at the three major experimental facilities have been made securely accessible via Fusion Grid. Additionally, the first fusion code placed on Fusion Grid, “TRANSP”—a widely used system for simulation of fusion experiments, has performed over 1,500 simulations taking over 10,000 CPU hours for nine different experimental fusion devices. Also, the simulation code that is used to study low-frequency turbulence in magnetized plasmas was recently made securely available on Fusion Grid. This collaborative technology is scalable to an international project like ITER.

Predictive Capability for Burning Plasmas

Intensive efforts during the past year have produced advances in the four major topical areas of fusion science: turbulence and transport, macroscopic equilibrium and stability, wave-plasma interactions and plasma heating, and edge/boundary layer plasma physics. Some of these advances have been made possible through the development of a sophisticated plasma control system that integrates theory, modeling, and planning of discharge scenarios described below, and some through careful planning and execution of complementary experiments among several relevant tokamaks to resolve important scientific issues. Some of these advances have been focused on projections of results from the present experiments to the larger ITER in the future. Several major highlights from these experiments and advanced computing are discussed below.

- **Favorable Confinement Projection for ITER**

  Collaborative experiments between the United States and Europe on the DIII-D tokamak (at General Atomics) and the JET tokamak (Culham Laboratory, UK) have obtained a result that indicates ITER might perform better than its baseline design assumption. Until now the standard projections of energy confinement for ITER have implied a strong degradation of energy confinement as the ratio of plasma pressure to magnetic pressure ("beta") was increased. Recent studies have shown that these experiments can vary beta by a factor of 3 without penalty to energy confinement. This result implies higher beta or plasma pressure affording either higher fusion power output and/or more ready access to steady-state operating modes in ITER.

- **Comprehensive Simulations of Transport from Turbulence in Tokamaks**

  Presently the most advanced code for calculating the heat and particle transport losses arising from turbulence in tokamak plasmas is ready to support a major advance in our understanding of turbulent transport once the computer resources available for this code are significantly increased to allow multiple runs for comparison with experiments.

- **Plasma Flows and Plasma Rotation**

  It has long been known that plasma conditions near the edge of a tokamak can have profound impact on energy confinement deep within the tokamak. Over the last year, experiments have revealed why: plasma flowing along magnetic field lines that do not close on themselves allows coupling of momentum from the edge into the center of the plasma, reducing the outward flow of energy.

- **Internal Transport Barriers**

  The plasma parameters of the internal transport barrier regime discovered on C-Mod have been significantly extended, in which profiles spontaneously peak with off-axis radio-frequency heating. Using increased levels of both on- and off-axis power (4 MW total), both temperature and density profiles became highly peaked, leading to a greatly increased central pressure approaching four atmospheres.

To confine a plasma at the temperatures and densities required for fusion energy production requires either a high magnetic field or an efficient confinement configuration. Achieving the latter requires an understanding of magnetohydrodynamic (MHD) equilibrium and stability. Since a plasma confined by a magnetic field is not in thermodynamic equilibrium, a variety of large-scale instabilities can occur.

An important instability that limits plasma pressure (and therefore fusion energy) is the "tearing mode," in which chains of magnetic islands, each only a few centimeters wide, form in the plasma, causing great heat loss and reducing energy confinement. Theory and experiment have established that these magnetic islands can be diminished by driving high frequency electrical current with surgical precision into them. However these islands are continually moving as the pressure and current in the plasma around them change. The challenge is to keep the high frequency electrical current focused on the moving islands. An example of this effort is the sophisticated feedback system being developed for ITER on the DIII-D tokamak, which automatically moves the plasma position (or adjusts the magnetic field magnitude) to keep the microwaves focused on the islands. Automatic correction using a unique real-time calculation to predict dynamic changes in plasma pressure has enabled stabilization of the largest and most difficult tearing modes with record accuracy and duration.

Proving the Role of Self-Driven Plasma Current in Instabilities at the Plasma Edge

Tokamak plasmas that would operate in ITER's nominal operating mode have regular pulsed instabilities in the plasma edge that produce pulsed heat and particle loads on the material surfaces in contact with plasma exhaust. If these pulses are too large, they can excessively erode the surfaces. Hence it is important to understand these instabilities. A new code, jointly developed by U.S. and U.K. scientists, successfully predicts most properties of these instabilities. A key feature in the theory is the existence of a large peak in the electrical current flowing in the plasma at the edge. While this current peak is expected from theory to be self-driven by the plasma, this prominent and unusual feature was never measured until this past year. Spectroscopic observations of an injected Lithium beam in the DIII-D tokamak measured this current peak for the first time. The magnitude and location of the current peak confirmed the theory of the edge instabilities and were close to the predicted values of the plasma's self-driven current. The confirmed theory of these instabilities will be valuable in devising ITER operating scenarios that minimize erosion of surfaces.

- **Active MHD Spectroscopy**

  Fusion power is proportional to the square of the plasma pressure. An upper limit to plasma pressure is set by the lowest order instability predicted by magnetohydrodynamic (MHD) theory. Referred to as the “kink mode,” it leads to termination of the plasma discharge. Recently it was shown in the DIII-D tokamak that this most important instability could be stabilized if the plasma is bounded by a nearby conducting wall and is rotating rapidly, allowing operation at up to twice the conventional pressure limit and implying a stabilizing mechanism connected with the rotation that dissipates the energy driving the instability. An elegant experimental technique (dubbed MHD spectroscopy) has been developed that allows the measurement of damping rates and rotation frequencies of these important modes. A set of coils is used as an antenna to apply a pulsed or rotating magnetic field with a large overlap in spatial structure with the basic unstable modes, and resonances are found. These measurements can now be compared to detailed code calculations that test various stabilizing mechanisms.

- **High Value of Plasma Pressure**

  During the past year, NSTX researchers successfully repaired toroidal magnetic field coils damaged during the FY 2003 experimental run, installed new diagnostic instruments, and began a new 18-week experimental campaign. At high plasma currents (1.2 million Amperes), very high values of plasma pressure were obtained, consistent with theoretical predictions (a ratio of plasma pressure to magnetic field pressure of nearly 40% was achieved).

- **Mode Conversion in Tokamak Plasmas**

  The first mapping of radio frequency wave mode conversion in tokamak plasmas was accomplished using a novel laser diagnostic. Both the long and short wavelength mode converted waves were simultaneously measured, and these modes were shown to drive DC electric current, with significant potential for current density profile control.

- **Control of Tokamak Instabilities**

  Very small asymmetries in magnetic fields, of the order of 1 ten-thousandth of the total field strength, can lead to "locked modes," which severely degrade performance and even lead to complete loss of confinement in tokamak plasmas. Experiments in C-Mod, together with coordinated experiments on other facilities around the world, including DIII-D, have established a basis for predicting the threshold for these effects in ITER and demonstrated successful suppression of these modes by application of compensating fields from specially designed external coils.

Understanding the interaction of plasma particles with electromagnetic waves is a fundamental topic in plasma science that has practical application to plasma heating and current drive.

- **Steady-State Plasmas for ITER**

  To operate ITER steady-state requires driving the plasma's electrical current (~10MA) by a combination of electromagnetic waves, particle beams, and the plasma's self-generated bootstrap current instead of using transformer coil induction. Plasma states were recently achieved in the DIII-D tokamak in which 100% of the plasma current was so obtained non-inductively, meeting or exceeding the parameters of ITER's projected steady-state operating scenario. At modest current where steady-state tokamaks are projected to operate, sufficient plasma pressure was obtained for an energy gain of 5 in ITER with 100% non-inductive operation and plasma confinement quality exceeding nominal expectations. The key was the use of high power millimeter waves at high frequencies (110GHz) to drive the current and control its spatial distribution. At lower plasma currents, 100% non-inductive operation was achieved with the transformer coil actually turned off and has afforded the first view of an almost completely self-organized tokamak plasma (except for being self-heated by the fusion reactions—ITER is needed for that). These plasmas and the “hybrid” scenarios reported last year are building the basis for ITER to achieve its high fusion energy gain and high fluence missions simultaneously.

Understanding edge plasma physics is important for tokamaks because the properties of the edge plasma affect both the flux of heat and particles to the material walls around the plasma and the confinement of heat and particles in the core of the plasma.

- **Predicting Tritium Co-deposition in ITER**

  In tokamaks with carbon first wall materials, the hydrogenic fuel species (tritium in ITER) is co-deposited on material surfaces with eroded carbon. Tritium thus trapped in ITER must be periodically removed. A first step toward such a removal scheme is to know where the tritium will be co-deposited. In the DIII-D tokamak, measurements and code simulations showed characteristic plasma flow patterns in the plasma boundary that implied deposits would form dominantly where the inner divertor leg contacted material surfaces. To obtain more definitive data, experiments were carefully executed following carbon-13 tracer elements that were injected into the plasma edge. Subsequent analysis of tile surfaces showed essentially all the carbon-13 was deposited where the inner divertor leg contacted material surfaces, confirming the result previously seen in the JET tokamak. These results suggest that in a divertor tokamak, the co-deposition area might be localized and predictable, the first step in being able to devise a tritium removal procedure.

Configuration Optimization

Since the inception of this program element in 1997, significant progress has been made in many confinement concepts. While Advanced Tokamak is included in the earlier section for its contributions to the Burning Plasma objective, it also contributes to Configuration Optimization by pushing the frontiers of tokamak research. The remaining material below reports only the accomplishments in concepts other than Advanced Tokamaks.

- Self organization of plasma plays an important role in the dynamics of fusion plasmas. The approach to self organization in plasma typically involves a relaxation process called Taylor relaxation. Taylor relaxation produces magnetic fluctuations that tend to degrade energy confinement. Recent research at University of Wisconsin using a small, reversed field pinch experiment successfully suppressed these magnetic fluctuations, leading to a ten-fold improvement in energy confinement. As a result, the plasma temperature in this experiment broke through the 10 million degree Celsius level. Research in the past year revealed that transport in the new mode of operation might be dominated by electrostatic fluctuations.

- Magnetic helicity is nature's way of "trapping" magnetic flux and electrical currents in some self-organized manner that allows magnetic and plasma energy to be transported in space and time. In a small university-scale experiment at the University of California in Davis, small balls of magnetic helicity (called compact toroids) have been accelerated to 200 km/s repetitively at a rate of 0.1 Hz in a self-switching coaxial plasma accelerator, and are being studied potentially for refueling tokamaks or modifying its density profile. In the past year the project demonstrated the scaling law for stopping a compact toroid in a toroidal magnetic field. Magnetic compression of the compact toroid upon injection into an axial magnetic field was measured. Injecting magnetic helicity into a tokamak is also a candidate for non-inductive start-up and for producing electrical currents in tokamak. Experiments addressing this application are in progress at the University of Washington in Seattle and at Caltech.
- When magnetic helicity is captured in a toroidal form in a simple vacuum vessel instead of a toroidal chamber, the configuration is a spheromak. The spheromak has the potential of a magnetic toroidal confinement system without the inconvenience (and cost) of a center stack of a tokamak. Because magnetic helicity decays due to dissipative processes, a fundamental issue in spheromak research is its sustainment. To that end, an important milestone in spheromak research was accomplished at the Sustained Spheromak Physics Experiment (SSPX) at the LLNL, in which short pulses of magnetic helicity were injected sequentially into the spheromak, and were successfully retained by the spheromak. In the past year, important advances were made in the computational modeling of this pulsed helicity injection technique.
- One method of heating plasma consists of compressing magnetized plasma by an imploding material wall, which may be solid, liquid, or gaseous. Currently an experiment is planned for studying the physics of such a compression which involves imploding a hollow cylindrical metallic shell by passing a large electrical current (about 10 megamperes) through the shell between two planar electrodes. A hole is present in at least one of the electrodes in order to insert magnetized plasma into the hollow of the shell. Therefore the body of the cylindrical shell needs to be imploded while the ends of the shell need to be sufficiently constrained in their motion so that they do not slide into the holes in the electrodes and thus lose electrical contact with the electrodes. The first experiment to address this issue was met with great success. An aluminum shell (containing no plasma), with a precise thickness profile designed with the help of detailed 2-D magnetohydrodynamic modeling guided by analytical theory, was successfully imploded with the desired imploding trajectory. Good electrical contact was maintained between the shell and the electrodes throughout the implosion. A radial convergence ratio of about 17 to 1 was achieved.
- A confinement configuration being investigated consists of a levitated magnetic dipole. The configuration is inspired by nature's way of confining plasma in planetary magnetospheres. After four years of development, the main components of the experimental system are finally installed. Initial testing of the system is expected to begin in the fall this year.

High Energy Density Physics

The combination of high plasma density and high plasma temperature needed for inertial fusion produces plasmas with very high energy densities. Energy densities in excess of 100 billion joules per cubic meter are of interest to an emerging field of physics called High Energy Density Physics, which cuts across several fields of contemporary physics including astrophysics. Plasmas at these energy densities are characterized by having pressures exceeding a million atmospheres.

The impact of heavy ion beams with a metallic hohlraum to produce highly energetic and intense x-rays to implode a material capsule has been considered an attractive approach to create fusion reactions and plasma states of high energy densities. Instead of using ions with energy in the range of 100's of billions of electron-volts (GeV) that are very expensive to produce, ions with much lower energy (and cost) in the 10's of million of electron-volts (MeV) may be used if the underlying plasma science issues could be understood and overcome. In the past year, significant progress has been made in understanding the plasma science of heavy ion beams, as well as in the physics of interaction of intense laser beams with materials.

- Ions carry electrical charges and create a net electric field, called the space-charge field, in an ion beam. The space-charge electric field acts to separate the ions and thus creates difficulties in focusing the beam to achieve high energy density. One approach to overcome this difficulty consists of passing the beam through a plasma, allowing the electrons in the plasma which are electrically opposite to neutralize the space-charge electric field of the ions. With the space-charge electric field significantly reduced or eliminated, the ions can then be focused by arranging their ballistic trajectories to converge. Experiments to demonstrate this focusing mechanism continue in the Neutralized Transport Experiment (NTX) at the LBNL, with more measurements of the beam parameters and with more comparisons with 3-D particle-in-cell modeling of the beam dynamics. In these experiments, ion beams of approximately 10 cm in diameter were focused down to a spot of less than a few millimeters. Separately, the High Current Experiment (HCX) at LBNL is studying the key physics related to beam transport at high intensities, including the effects of imperfections in alignment and focusing fields, image charge effects from beam proximity to the conducting wall, collective oscillations and instabilities, beam halo particles and electron effects.
- An exciting new scientific development in recent years in the area of high energy density physics is the use of petawatt (a thousand-trillion-watt) lasers to heat an already dense solid. As applied to inertial fusion, the concept consists of using a petawatt laser to heat and ignite a fusionable capsule that is pre-compressed by another laser. The concept is called Fast Ignition. When the intense laser beam impinges on the capsule, the intense radiation accelerates the electrons in the capsule to relativistic velocities. The transport of these relativistic electrons in the material governs the effectiveness of heating the capsule. In the past year, researchers at General Atomics and Lawrence Livermore National Laboratory, working with British and Japanese experimental groups and facilities, continued to generate experimental data that will elucidate the transport of these relativistic electrons in dense matter.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Tokamak Experimental Research	**44,842**	**45,147**	**43,765**

The tokamak magnetic confinement concept has thus far been the most effective approach for confining plasmas with stellar temperatures within a laboratory environment. Many of the important issues in fusion science are being studied in coordinated programs on the two major U.S. tokamak facilities, DIII-D at General Atomics and Alcator C-Mod at the Massachusetts Institute of Technology. Both DIII-D and Alcator C-Mod are operated as national collaborative science facilities with research programs established through public research forums, program advisory committee recommendations, and peer review. There is also a very active program of collaboration with comparable facilities abroad aimed at establishing an international database of Tokamak experimental results. In association with the International Tokamak Physics Activity (ITPA), both DIII-D and Alcator C-Mod continue to increase their efforts on joint experiments with other major facilities in Europe and Japan in support of ITER-relevant physics issues.

Both DIII-D and Alcator C-Mod will focus on using their flexible plasma shaping and dynamic control capabilities to attain good confinement and stability. They do this by controlling the distribution of current in the plasma with electromagnetic wave current drive. The interface between the plasma edge and the material walls of the confinement vessel is managed by means of a “magnetic divertor.” Achieving high performance regimes for longer pulse duration, approaching the steady state, will require simultaneous advances in all of the scientific issues listed above.

▪ **DIII-D Research**	**24,241**	**22,842**	**22,663**

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 DIII-D experimental program contributes to all four key Magnetic Fusion Energy (MFE) fusion topical science areas of energy transport, stability, plasma-wave interactions, and boundary physics, and to various thrust areas that integrate across topical areas to support the goal of achieving burning plasma. In the past two years, the investigation of ITER relevant discharge scenarios has gained emphasis in the DIII-D experimental program. The level of effort for all DIII-D physics research topics in FY 2006 decreases from FY 2005, but the effort to support burning plasma physics, specifically for ITER, will remain a priority. This research elucidates the effects of plasma edge instabilities and high pressure in various plasma confinement regimes, extending the duration of stable plasma operation, and helping build cross-machine data bases using dimensionless parameter techniques.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

The program will also continue the investigation of the scientific basis for optimization of the tokamak approach to fusion production. This research includes investigation of different modes of operation of fusion plasmas for enhancing the attractiveness of tokamak systems. Research on four topical sciences areas mentioned above will continue. The refurbishment and commissioning of the Ion-Cyclotron Radio Frequency (ICRF) system, that was built about 4 years ago, started in FY 2003, and it will be available for these experiments in FY 2006. This system will provide additional electron heating capability and improve the current drive provided by the ECH system and further increase capability to control current profile. The activities in all these areas are interrelated, and they will improve the physics basis and demonstration of a long-pulse, high-performance tokamak.

▪ **Alcator C-Mod Research**..	**8,268**	**8,636**	**8,433**

Alcator C-Mod is a unique, compact tokamak facility that uses intense magnetic fields to confine high-temperature, high-density plasmas in a small volume. It is also unique in the use of metal (molybdenum) walls to accommodate high power densities.

By virtue of these characteristics, Alcator C-Mod is particularly well suited to operate in plasma regimes that are relevant to future, much larger fusion tokamaks, as well as to compact, high field, high density burning plasma physics tokamaks. Burning plasmas can be achieved for short pulses in a low cost tokamak by trading high magnetic field for large size (and cost). Alcator C-Mod has made significant contributions to the world fusion program in the areas of plasma heating, stability, and confinement in high field tokamaks; these are important integrating issues related to ignition and burning of fusion plasma. In FY 2006, compact high field tokamak regimes and operating scenarios required for ignition in compact devices will be further explored. Resources will be increasingly focused on ITER relevant topics such as understanding the physics of the plasma edge in the presence of large heat flows, measuring the effects of and mitigating disruptions in the plasma, controlling the current density profile for better stability, noninductively driving a large part of the plasma current and helping build cross-machine data bases using dimensionless parameter techniques.

Research will also continue to examine the physics of the operational density limit, power and particle exhaust from the plasma, mechanisms of self-generation of plasma flows, and the characteristics of the operating modes achieved when currents are driven by electromagnetic waves. It will also focus on studying transport in the plasma edge at high densities and in relation to the plasma density limit. A new diagnostic neutral beam will further improve visualization of turbulence in the edge and core of high density plasmas, and new diagnostics will shed light on the physics of temperature and density profiles, whose features are now thought to be the key to predicting tokamak behavior. Active MHD spectroscopy, a novel method for sensing the onset of instability, will continue in FY 2006. The new lower hybrid (microwave) current drive system will be in operation, and experiments will continue using it for control of the current density profile. Challenges resulting from the use of higher power levels than ever before will be dealt with in relation to all of the particular efforts mentioned above.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **International Collaborations**...	**4,802**	**4,863**	**4,860**

In addition to their work on domestic experiments, scientists from the United States participate in leading edge scientific experiments on fusion facilities abroad, and conduct comparative studies to enhance understanding of underlying physics. The Fusion Energy Sciences program has a long-standing policy of seeking collaboration internationally in the pursuit of timely scientific issues. This allows U.S. scientists to have access to the unique capabilities of facilities that exist abroad. These include the world's highest performance tokamaks (JET in England and JT-60 in Japan), a stellarator (the Large Helical Device) in Japan, a superconducting tokamak (Tore Supra) in France, and several smaller devices. In addition, the U.S. is collaborating with South Korea on the design of plasma diagnostics for the long-pulse, superconducting, advanced tokamak (KSTAR). These collaborations provide a valuable link with the 80% of the world's fusion research that is supported and conducted outside the United States.

International collaboration will continue on these unique facilities abroad at the same level of effort. In FY 2006, an expansion on joint International Tokamak Physics Activity (ITPA) with Japan, Europe, and Russia will continue to enhance collaboration on physics issues related to tokamak burning plasmas. In FY 2006, the collaborations with international programs will also focus on ways of using the unique aspects of these facilities to make progress on the four key MFE Science issues—energy transport, stability, plasma-wave interaction and boundary physics.

▪ **Diagnostics**..	**3,926**	**3,870**	**3,870**

Support of the development of unique measurement capabilities (diagnostic instruments) that provide an understanding of the plasma behavior in fusion research devices will continue. Some of this research supports diagnostics for burning plasma physics, which will be first demonstrated on current experiments such as DIII-D in the U.S. and JET in Europe (through collaborative programs) to investigate their applicability to ITER. Among the key areas of diagnostic research are the development of: (1) techniques to measure the loss of energy/heat and particles from the core of magnetically confined plasmas, including techniques aimed at understanding how barriers to energy/heat loss can be formed in plasmas; (2) methods to measure the production, movement, and loss/retention of the particles that are needed to ignite and sustain a burning plasma; and (3) new approaches that are required to measure plasma parameters in alternate magnetic configurations, which add unique constraints due to magnetic field configuration and strength, and limited lines of sight into the plasma. The requested funding level in FY 2006 supports research that will enhance our understanding of critical plasma phenomena and the means of affecting these phenomena to improve energy and particle confinement in tokamaks and innovative confinement machines. Currently supported programs underwent a competitive peer review in FY 2004.

▪ **Other**	**3,605**	**4,936**	**3,939**

Funding for educational activities in FY 2006 will support research at historically black colleges and universities, graduate and postgraduate fellowships in fusion science and technology, summer internships for undergraduates, a summer workshop for minority high school students, and outreach efforts related to fusion science and enabling R&D.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Alternative Concept Experimental Research	**57,319**	**60,874**	**49,940**

A significant amount of research is focused on alternative concepts, aimed at extending fusion science and identifying innovative concepts that could improve the economic and environmental attractiveness of fusion, thereby lowering the overall programmatic risk and cost of the Fusion Energy Sciences program in the long term. The largest element of the alternative concepts program is the NSTX at Princeton Plasma Physics Laboratory that began operating in FY 2000. Like DIII-D and Alcator C-Mod, NSTX is also operated as a national collaborative scientific facility. The Madison Symmetric Torus (MST) is at an intermediate stage of development between a small-scale experiment and a major facility.

▪ **NSTX Research**	**16,428**	**16,466**	**16,172**

NSTX is one of the world's two largest spherical torus confinement experiments. NSTX has a unique, nearly spherical plasma shape that complements the doughnut shaped tokamak and provides a test of the theory of toroidal magnetic confinement as the spherical limit is approached. Plasmas in spherical tori have been predicted to be stable even when high ratios of plasma-to-magnetic pressure and large self-driven current fractions exist simultaneously in the presence of a nearby conducting wall bounding the plasma. If these predictions are verified in detail, it would indicate that spherical tori use applied magnetic fields more efficiently than most other magnetic confinement systems and could, therefore, be expected to lead to more cost-effective fusion power systems. An associated issue for spherical torus configurations is the challenge of driving plasma current via radio-frequency waves or biased electrodes. Such current drive techniques are essential to achieving sustained operation of a spherical torus.

The spherical torus plasma, like all high beta plasmas, is characterized by high velocity fast ions with a large radius of gyration relative to plasma size that could potentially lead to new plasma behaviors of interest. In FY 2006, NSTX will not operate, but the proposed funding will allow the NSTX national team to analyze data from FY 2004-2005 and carry out scenario modeling and planning for future experiments. This will help the NSTX team to achieve high plasma pressure and good energy confinement efficiency for pulse lengths much longer than the energy replacement time when operations resume in FY 2007.

▪ **Experimental Plasma Research**	**21,075**	**21,791**	**18,832**

With the emphasis on developing the fundamental understanding of the plasma science that underpins innovative fusion concepts, this research element is a broad-based research activity, conducted in 25 experiments and theory support projects, involving 30 principal investigators and co-principal investigators in 11 universities, 4 national laboratories and industry. Because of the small size of the experiments and the use of sophisticated technologies, the research provides excellent educational opportunities for students and post-docs, and helps to develop the next generation of fusion scientists. In order to foster a vigorous breeding ground for research, each project is competitively peer reviewed on a regular basis of three to five years, so that a portfolio of projects with high performance is maintained.

Current projects in this program element include fundamental investigations into concepts such as, advanced stellarator configurations, tokamak innovations, the levitated dipole, field-reversed configurations (FRC), spheromaks, and magnetized target fusion.

Examples of the research being pursued in these experiments include:

- Complementing the advanced tokamak research on DIII-D and Alcator C-Mod is the exploratory work on the High Beta tokamak (HBT) at Columbia University. Its goal is to demonstrate the feasibility of stabilizing instabilities in high pressure tokamak plasma using a combination of a close-fitting conducting wall, and active feedback. This work is closely coordinated with the DIII-D program, and promising results have already been achieved on DIII-D.
- Research in advanced stellarators, such as the Helically Symmetric Experiment at the University of Wisconsin explores the symmetry characteristics that make quasisymmetrical stellarators different from all other toroidal confinement systems. It is studying transport attributable to fluctuations, and exploring stability and beta limits. Such studies will be applicable to the NCSX, a proof of principle experiment currently under fabrication.
- Field-reversed configurations and spheromaks are toroidal plasma confinement configurations like the tokamak but without the need of a center pole, making them candidates for highly compact fusion reactors. In field-reversed configurations (FRC), current research is exploring an avenue to form and sustain the FRC using a rotating magnetic field (RMF). The main experimental goal in FY 2006 is to form a clean RMF generated FRC so that detailed physics investigations of its energy confinement and transport characteristics could begin.
- Spheromaks are plasmas with self-organized internal plasma currents which generate magnetic fields that confine the plasma, eliminating the toroidal magnets and ohmic heating transformer which necessarily thread the vacuum vessel in the tokamak. Current research aims at generating, amplifying and sustaining these internal plasma currents (related to its magnetic helicity) by the use of coaxial plasma guns (known as coaxial helicity injection).
- Research in magnetized target fusion aims at combining the favorable features of both magnetic and inertial confinement to create fusion reactions at a plasma density considerably higher than conventional Magnetic Fusion Energy (MFE), but using drivers considerably less powerful and cheaper than Inertial Fusion Energy. The main experimental objectives by FY 2006 are to produce high-density magnetized plasma with sufficient lifetime and to translate the magnetized plasma into a mock-up liner, and to resolve the issue of using a deformable liner or an alternative liner for compressing the plasma.
- The Levitated Dipole Experiment (LDX) explores plasma confinement in a novel magnetic dipole configuration similar to the magnetic field that confines the plasma in the earth's magnetosphere.

A review is planned of all the major experiments with annual budgets of about $1,000,000 or more, with the intention of reducing the number of concepts pursued. The projects to be subjected to this review include the Spheromak experiment (SSPX) at Lawrence Livermore National Laboratory, the Field Reversed Configuration experiment at the University of Washington – Seattle, and the Magnetized Target Fusion experiment at the Los Alamos National Laboratory, together with the experiments that would be normally due for review in FY 2005.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **High Energy Density Physics**	**13,876**	**15,341**	**8,086**

The combination of high plasma density and high plasma temperature needed for inertial fusion produces plasmas with very high energy densities. Energy densities in excess of 100 billion joules per cubic meter are of interest to inertial fusion, and their study is an emerging field of physics called High Energy Density Physics (HEDP), which cuts across several fields of contemporary physics including astrophysics. Plasmas at these energy densities are characterized by having pressures exceeding a million atmospheres. In the laboratory these high energy density conditions are produced typically through the use of high power lasers, ion beams, or convergence of high density plasma jets. With a reduction of $7,255,000 in heavy ion beam research in FY 2006, research in heavy ion beams will be focused on studying the scientific basis for spatial and temporal compression of the beams to create extremely bright beams for high energy density physics research in the near term. The research efforts in Fast Ignition and high Mach number plasma jets will be retained at a level of about $3,000,000. Both Fast Ignition and dense plasma jets are exciting new fields of HEDP, which are attracting world-wide scientific attention. This is evidenced by the numerous papers on these two subjects at the recent 2004 American Physical Society Division of Plasma Physics meeting. The relativistic physics of thermal transport in Fast Ignition will be explored. Modest efforts will be initiated to explore experimental techniques to produce high Mach number, high density plasma jets in the laboratory, and study their application to HEDP. Research in this area will be guided by the recommendations of the recent Report of the Office of Science and Technology Interagency Working Group Task Force on High Energy Density Physics (July 2004) and two NRC reports entitled “Frontiers in High Energy Density Physics” and “Connecting Quarks to the Cosmos.”

▪ **Madison Symmetrical Torus**	**5,174**	**6,503**	**6,150**

The goal of the Madison Symmetric Torus (MST) experiment is to obtain a fundamental understanding of the physics of reversed field pinches (RFP), particularly magnetic fluctuations and their macroscopic consequences, and to use this understanding to develop the RFP fusion configuration. The plasma dynamics that limit the energy confinement, the ratio of plasma pressure to magnetic field pressure, and the sustainment of the plasma current in RFP are being investigated in the MST experiment. Magnetic fluctuations and its macroscopic consequences including transport, dynamo, stochasticity, ion heating, magnetic reconnection, and momentum transport, have applications across a wide spectrum of fusion science and astrophysics, to which the MST experiment thus contributes. MST is one of the four leading experiments in RFP research in the world, and is unique in that it pioneered the reduction of magnetic fluctuations by current density profile control. This approach has led to a ten-fold increase in energy confinement. Continual developments in the experimental facility and the theory build-up in FY 2003, FY 2004 and FY 2005 will enable in FY 2006 productive studies of one or more of the following techniques as mechanisms for driving and controlling the current profile, as well as for heating and fueling the plasma: inductive electric field programming, electromagnetic waves, oscillating field helicity injection, neutral beams, and pellet injection. With potentially improved plasmas in MST obtained with one or more of the most highly developed of these techniques, separately or in combination, the major experimental undertaking in FY 2006 will be to measure the improved confinement and sustainment in MST with greatly reduced dynamo activity.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
▪ **National Compact Stellarator Experiment (NCSX)**	**766**	**773**	**700**

NCSX Research supports the research portion of the program to be executed with the NCSX Experiment at PPPL. This involves participation and a leadership role within the National Compact Stellarator Program (NCSP). PPPL, ORNL, and LLNL are the participants in NCSX research that keeps abreast of physics developments in domestic and international stellarator research, factoring those developments into the planning of the NCSX experimental program, as well as preparation of long-lead-time physics analysis tools for NCSX application. These tools have a dual use: setting physics requirements for hardware upgrades and interpreting data from future NCSX experiments. Some long-lead hardware upgrades will be designed, such as plasma control systems. The NCSX team will adapt tools that are available, or being developed, to establish requirements and physics designs for magnetic diagnostic upgrades and e-beam mapping. Finally, a research forum will be held to invite and encourage participation by the U.S. community in the research and diagnostics preparations for NCSX.

Theory	**25,367**	**25,460**	**24,640**

The theory and modeling program provides the conceptual underpinning for the fusion sciences program. Theory efforts meet the challenge of describing complex non-linear plasma systems at the most fundamental level. These descriptions range from analytic theory to highly sophisticated computer simulation codes, both of which are used to analyze data from current experiments, guide future experiments, design future experimental facilities, and assess projections of their performance. Analytic theory and computer codes represent a growing knowledge base that, in the end, is expected to lead to a predictive understanding of how fusion plasmas can be sustained and controlled.

The theory and modeling program is a broad-based program with researchers located at five national laboratories, over 30 universities, and three industries. Institutional diversity is a strength of the program, since theorists at different types of institutions play different roles in the program. Theorists in larger groups, that are mainly at national laboratories and industry, generally support major experiments, work on large problems requiring a team effort, or tackle complex issues requiring multidisciplinary teams while those at universities generally support smaller, innovative experiments or work on more fundamental problems in plasma physics.

The theory program is composed of two elements—tokamak theory and alternate concept theory. The main thrust of the work in tokamak theory is aimed at developing a predictive understanding of advanced tokamak operating modes and burning plasmas, both of which are important to ITER. These tools are also being extended to innovative or alternate confinement geometries. In alternate concept theory, the emphasis is on understanding the fundamental processes determining equilibrium, stability, and confinement in each concept.

SciDAC	**3,319**	**4,275**	**4,275**

An important element of the Office of Science's Scientific Discovery through Advanced Computing (SciDAC) program is the FES funded portion. Major scientific challenges exist in many areas of plasma and fusion science that can best be addressed through advances in scientific supercomputing. In late FY 2004, a new round of FES SciDAC projects was initiated. The selected projects are focused on the topics of microturbulence simulation, extended magnetohydrodynamics modeling, and simulation of

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

electromagnetic wave-plasma interaction, which will provide a fundamental understanding of plasma science issues important to a burning plasma, and lay the groundwork for the fusion simulation project. The new projects will continue to involve collaborations among physicists, applied mathematicians and computer scientists. In late 2005, the FES program and the Advanced Scientific Computing Research program are planning to begin one or two prototype focused integration initiatives, based on a competitive peer review process.

In FY 2006, these prototype focused integration initiatives, along with the three continuing SciDAC projects, will emphasize the latest computing techniques and will make use of rapid developments in computer hardware to attack complex problems involving a large range of scales in time and space, including plasma turbulence and transport, large scale instabilities and stability limits, boundary layer/edge plasma physics, and wave-plasma interaction. These problems were beyond the capability of the fastest computers in the past, but advancements in computation should enable good progress on problems that once seemed intractable. The objective of the advanced computing activities, including the SciDAC program, is to promote the use of modern computer languages and advanced computing techniques to bring about a qualitative improvement in the development of models of plasma behavior. This will ensure that advanced modeling tools are available to support the preparations for a burning plasma experiment and fruitful collaboration on major international facilities.

General Plasma Science...	**11,876**	**12,341**	**13,900**

The general plasma science program is directed toward basic plasma science and engineering research. This research strengthens the fundamental underpinnings of the discipline of plasma physics that make contributions in many basic and applied physics areas. Principal investigators at universities, laboratories and private industry carry out the research. A critically important element is the education of plasma physicists. Continuing elements of this program are the NSF/DOE Partnership in Basic Plasma Science and Engineering, the Plasma Physics Junior Faculty Development Program and the basic and applied plasma physics program at DOE laboratories. In FY 2006, the program will continue to fund proposals that have been peer reviewed. Funding will also continue for the Fusion Science Center program that was started in FY 2004. The Department plans to spend approximately $2,000,000 on the Fusion Science Center program each year in FY 2005 and FY 2006. Basic plasma physics user facilities will be supported at both universities and laboratories, sharing costs with NSF where appropriate. Atomic and molecular data for fusion will continue to be generated and distributed through openly available databases. The FES program will continue to share the cost of funding the multi-institutional plasma physics frontier science center funded by NSF starting in FY 2003.

SBIR/STTR..	**0**	**6,966**	**6,251**

FY 2004 excludes $5,979,000 and $717,000 which was transferred to SBIR and STTR programs, respectively. The FY 2005 and FY 2006 amounts are the estimated requirements for the continuation of these programs.

Total, Science	**142,723**	**155,063**	**142,771**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Tokamak Experimental Research	
▪ **DIII-D** This reflects the decrease in DIII-D research efforts consistent with the reduction in experimental operations reflected under the Facility Operations subprogram.	-179
▪ **Alcator C-Modification** This decrease will reduce the effort in experiments on controlling the tokamak current density by means of the lower hybrid microwave system.	-203
▪ **International** This decrease will reduce the effort slightly on the JET diagnostic collaboration.	-3
▪ **Other** The decrease will reduce funding for educational programs.	-997
Total, Tokamak Experimental Research	**-1,382**
Alternate Concept Experimental Research	
▪ **National Spherical Torus Experiment (NSTX)** Since NSTX will not be operating, less travel funding for collaborators is required.	-294
▪ **Experimental Plasma Research** This decrease will eliminate one major Innovative Confinement Concept from the program. In the reduction, $955,000 comes from a one-time add-on to several "small experiments" included in the FY 2005 appropriation.	-2,959
▪ **High Density Physics** This reduction will reduce the level of research on Heavy Ion Beams at the Lawrence Berkeley National Laboratory, the Lawrence Livermore National Laboratory, the Princeton Plasma Physics Laboratory, and university research supporting heavy ion beams at the University of Maryland, MIT, and elsewhere.	-7,255
▪ **Madison Symmetric Torus (MST)** This reduction reflects the one-time add-on in FY 2005 toward the partial purchase of the hardware components for a programmable power supply.	-353
▪ **National Compact Stellarator Experiment (NCSX)** This decrease will eliminate the establishment of requirements and physics designs for control algorithms and trim coils.	-73
Total, Alternative Concept Experimental Research	**-10,934**
Theory This decrease will eliminate support for one grant in the theory portfolio and result in the reduction of two scientists doing theory work at national laboratories.	-820

	FY 2006 vs. FY 2005 ($000)
General Plasma Science The increase will expand the number of grant applications funded under the NSF/DOE Partnership in Basic Plasma Science and Engineering, and fund the renewal and expansion of the DOE national laboratory-based Opportunities in Basic Plasma Science program.	+1,559
SBIR/STTR Support for SBIR/STTR is provided at the mandated level.	-715
Total Funding Change, Science	**-12,292**

Facility Operations

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Facility Operations					
DIII-D	30,194	32,849	28,711	-4,138	-12.6%
Alcator C-Mod	14,014	13,402	13,097	-305	-2.3%
NSTX	19,189	18,069	14,535	-3,534	-19.6%
NCSX	15,921	17,500	15,900	-1,600	-9.1%
ITER Preparations	3,155	4,947	6,000	+1,053	+21.3%
ITER MIE TEC	0	0	46,000	+46,000	--
GPP/GPE/Other	3,217	3,176	3,276	+100	+3.1%
Total, Facility Operations	85,690	89,943	127,519	+37,576	+41.8%

Description

The mission of the Facility Operations subprogram is to manage the operation of the major fusion research facilities and the fabrication of new projects to the highest standards of overall performance, using merit evaluation and independent peer review. The facilities will be operated in a safe and environmentally sound manner, with high efficiency relative to the planned number of weeks of operation, with maximum quantity and quality of data collection relative to the installed diagnostic capability, and in a manner responsive to the needs of the scientific collaborators. In addition, fabrication of new projects and upgrades of major fusion facilities will be accomplished in accordance with the highest standards and with minimum deviation from approved cost and schedule baselines.

Benefits

The Facility Operations subprogram operates the major facilities needed to carry out the scientific research program in a safe and reliable manner. This subprogram ensures that the facilities meet their annual targets for operating weeks and that they have state of the art, flexible systems for heating, fueling, and plasma control required to optimize plasma performance for the experimental programs. Further, this subprogram fabricates and installs the diagnostics that maximize the scientific productivity of the experiments. Finally, this subprogram provides for the fabrication of new facilities such as NCSX, and for participation in the international collaboration on ITER through the preparation for and the start of the U.S. Contributions to ITER MIE project. TEC funds are budgeted in this sub-program. OPC funds are budgeted in Enabling R&D sub-programs.

Supporting Information

This activity provides for the operation, maintenance and enhancement of major fusion research facilities; namely, DIII-D at General Atomics, Alcator C-Mod at MIT, and NSTX at PPPL. These collaborative facilities enable U.S. scientists from universities, laboratories, and industry, as well as visiting foreign scientists, to conduct world-class research funded in the Science and Enabling R&D subprograms. The facilities consist of magnetic plasma confinement devices, plasma heating and current drive systems, diagnostics and instrumentation, experimental areas, computing and computer networking facilities, and other auxiliary systems. The Facility Operations subprogram provides funds for operating and maintenance personnel, electric power, expendable supplies, replacement parts, system modifications and facility enhancements.

Funding is also provided for the continuation of the National Compact Stellarator Experiment (NCSX) MIE project at PPPL. In FY 2006, the project will be in its fourth year; PPPL will continue with the fabrication of the device with the focus being on winding the modular coils and assembling the vacuum vessel.

Funding is also provided for ITER preparations, in which U.S. scientists and engineers in laboratories, universities, and industry will be involved in various technical activities that support both ITER negotiations for an international ITER program as well as planning for the U.S. Contributions to ITER project. This MIE is planned to start in mid-FY 2006 assuming negotiations are completed in FY 2005. U.S. activities in support of ITER will be managed by the U.S. ITER Project Office located at PPPL.

In the expectation that the U.S. Contributions to ITER MIE begins in FY 2006, funding is identified for the U.S. contributions of equipment, personnel, and limited amount of cash for the U.S. share of common costs on site such as installation and testing. As an MIE, the cost and schedule baselines will be managed in accordance with DOE Order 413.3 project management requirements. A Total Project Cost (TPC) funding profile is identified in the Significant Program Shifts section of the FES budget, consisting of Total Estimated Cost (TEC) funding requested in this subprogram and Other Project Costs (OPC) funding requested in the Enabling R&D subprogram. The TEC includes all direct costs for the MIE including all U.S. hardware procurements, hardware installation, U.S. personnel assigned to the ITER project abroad, cash for common needs such as ITER project infrastructure, contingency and operation of the U.S. ITER Project Office. The OPC includes R&D and design tasks in support of the procurements comprising the U.S. Contributions to ITER MIE. These OPC tasks will be performed by U.S. fusion scientists and engineers currently part of the fusion program.

Funding is also included in this subprogram for general plant projects (GPP) and general purpose equipment (GPE) at PPPL. The GPP and GPE funding supports essential facility renovations, and other necessary capital alterations and additions, to buildings and utility systems. Funding is also provided for the fourth year of a five year effort to support the move of ORNL fusion personnel and facilities to a new location at ORNL.

FY 2004 Facility Operations Accomplishments

In FY 2004, funding was provided to operate facilities in support of fusion research experiments and to upgrade facilities to enable further research in fusion and plasma science. Examples of accomplishments in this area include:

- GA completed the strengthening of the internal “plasma control” coils for stability experiments.
- PPPL NCSX has ordered both the modular coil winding forms and vacuum vessel sector prototypes from each of four industrial supplier teams and has received both vacuum vessel sector prototypes.

  PPPL awarded contracts to two industrial teams in October 2003 for manufacturing development of the NCSX modular coil winding forms. These are steel structures that support the modular coil windings and locate them to high accuracy. The purpose of these contracts was to develop the manufacturing processes for the forms through fabrication of full-scale prototypes. The project awarded a follow-on contract for the production order to one of these teams in early FY 2005. In addition, PPPL awarded contracts in October 2003 to two industrial suppliers for manufacturing development of the NCSX vacuum vessel. The vacuum vessel is a highly shaped structure with stringent requirements on vacuum quality and magnetic permeability. The purpose of these contracts was to develop the manufacturing processes to be used in the fabrication of the vessel through fabrication of a prototype sector. Just like the modular coil winding forms, the project awarded a follow-on contract for the production order to one of these suppliers in early FY 2005.

- Operation of Alcator C-Mod was extended at high field to plasma currents up to 2 million amperes, opening up new operational space for physics investigations.
- New non-axisymmetric magnetic field coils were designed, constructed, and installed on Alcator C-Mod and are now in routine operation. They provide a critical new tool to investigate the effects of error fields on the dynamics of MHD instabilities, and have permitted the extension of operation to higher plasma currents.

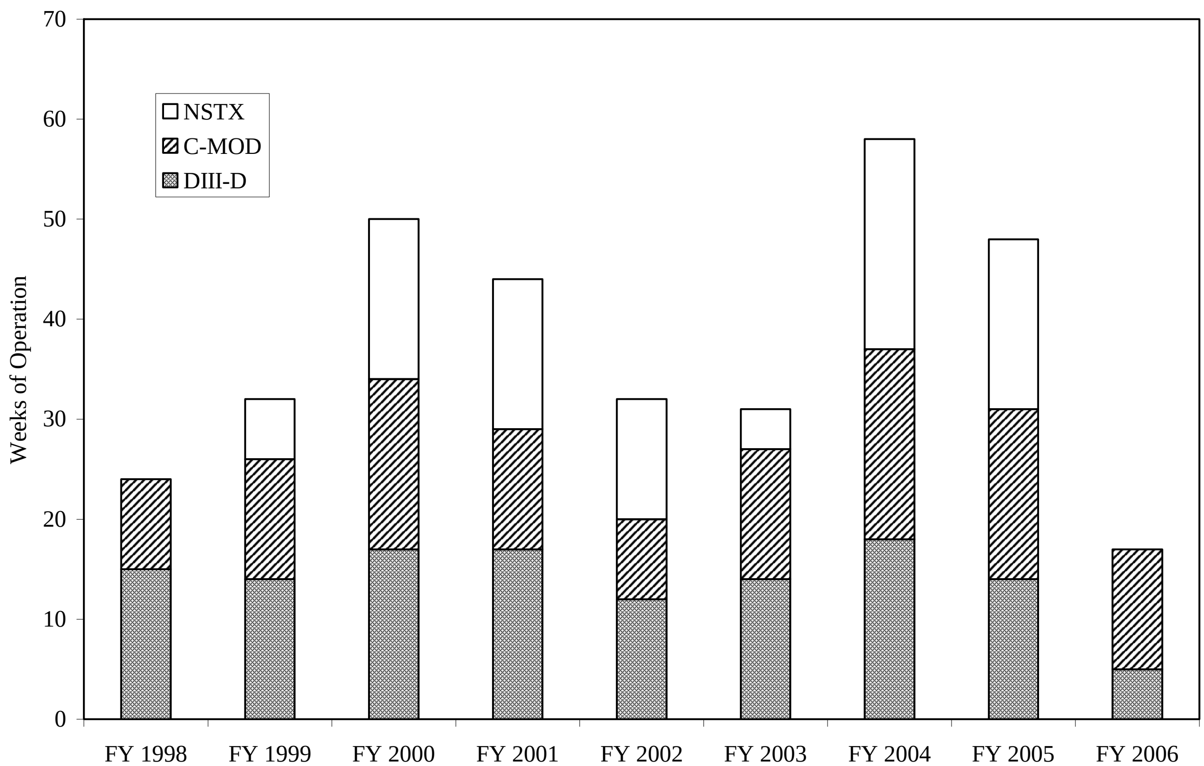
The table and chart below summarize the recent and longer-term history of operation of the major fusion facilities.

Weeks of Fusion Facility Operation

(weeks of operations)

	FY 2004 Results	FY 2005 Target	FY 2006 Target
DIII-D	18	14	5
Alcator C-Mod	19	17	12
NSTX	21	17	0
Total	58	48	17

Historical Perspective on Operations of the Major Fusion Experimental Facilities



Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
DIII-D	**30,194**	**32,849**	**28,711**

Provide support for operation, maintenance, and improvement of the DIII-D facility and its auxiliary systems. In FY 2006, these funds support 5 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram. These funds also provide for completing the rotation of a neutral beam line and modest progress on other high priority DIII-D upgrades and refurbishments.

Alcator C-Mod	**14,014**	**13,402**	**13,097**

Provide support for operation, maintenance, and improvement of the Alcator C-Mod facility and its auxiliary systems. In FY 2006, these funds support 12 weeks of single shift plasma operation during which time essential scientific research will be performed as described in the science subprogram.

National Spherical Torus Experiment (NSTX)	**19,189**	**18,069**	**14,535**

Provide support for maintenance and minor upgrades, such as an imaging reflectometer, a neutron collimator, and an additional laser for the Thomson scattering system. In FY 2006, there is no funding for operation, only for minor facility upgrades that will enable long pulse, high beta experiments in the future. This reduction in operating weeks will delay progress in all areas of spherical torus research on NSTX.

National Compact Stellarator Experiment (NCSX)	**15,921**	**17,500**	**15,900**

Funding in the amount of $15,900,000 is requested for the continuation of the NCSX Major Item of Equipment, which was initiated in FY 2003 and consists of the design and fabrication of a compact stellarator proof-of-principle class experiment. These funds will allow for the continuation of procurement of major items and fabrication of the device. This fusion confinement concept has the potential to be operated without plasma disruptions, leading to power plant designs that are simpler and more reliable than those based on the current lead concept, the tokamak. The NCSX design will allow experiments that compare confinement and stability, in tokamak and stellarator configurations. The current total estimated cost (TEC) of NCSX increases to $90,839,000, with completion estimated to be in May 2009. A new cost and schedule performance baseline will be developed consistent with the FY 2006 budget request and expected out years in the mid-2005 time frame.

A key performance target for FES is to keep the cost-weighted mean percent variance for the NCSX project's cost and schedule baseline within 10%. To maintain this target, FES must monitor NCSX progress closely throughout the fiscal year. Utilizing PART, as well as effective project management both at DOE and PPPL, the project continues to be well within the 10% variance.

ITER Preparations	**3,155**	**4,947**	**6,000**

Funding in the amount of $6,000,000 is provided to continue to completion the ITER transitional activities such as safety, licensing, project management, preparation of specifications and system integration. U.S. personnel will participate in these activities in preparation for U.S. participation in the international ITER project. In addition, preparations will be made to qualify U.S. vendors to supply

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

equipment for the project. The ITER Preparations activity is not part of the U.S. Contributions to ITER MIE, but is in preparation for the MIE. Discussions are proceeding on whether these costs should be accounted for within the ITER TPC. A determination will be part of the Critical Decision – 1 process.

U.S. Contributions to ITER - (MIE TEC)	**0**	**0**	**46,000**

U.S. Contributions to ITER is a proposed MIE which supports the international project called ITER, whose mission is to demonstrate the scientific and technological feasibility of fusion energy and whose design and supporting R&D were essentially completed during the period 1992 to 2001. Currently, the U.S. is negotiating an international agreement with the European Union (EU), Japan, Russian Federation, China and South Korea not only for the fabrication of the facility, but also the operation, deactivation and decommissioning of ITER. For each of the ITER program phases, the U.S. is negotiating financial participation at approximately the 10% level. After the negotiated international agreement is completed and initialed by the negotiators and then signed by the parties' governments, an ITER legal entity would exist. Following the appointment of a Director General, the ITER Organization, which will be formed from personnel from all the parties and will be responsible for the realization of the ITER facility and program, would mobilize at the ITER site. The current schedule for these events is consistent with the need for all parties to begin their contributions to ITER in mid-FY 2006.

ITER has been designed to provide major advances in all of the key areas of magnetically confined plasma science. ITER's size and magnetic field will provide for study of plasma stability and transport in regimes unexplored by any existing fusion research facility worldwide. Owing to the intense plasma heating by fusion products, it will also access previously unexplored regimes of energetic particle physics. Because of the very strong heat and particle fluxes emerging from ITER plasmas, it will extend regimes of plasma-boundary interaction well beyond previous experience. The new regimes of plasma physics that can be explored for long duration, and the interactions among the anticipated phenomena, are characterized together as the new regime of "burning plasma physics."

The ITER design is based on scientific knowledge and extrapolations derived from the operation of the world's tokamaks over the past decades and on the technical know-how flowing from the fusion technology research and development programs around the world. The ITER design has been internationally validated by wide-ranging physics and engineering work, including detailed physics and computational analyses, specific experiments in existing fusion research facilities and dedicated technology developments and tests performed during from 1992 to the present.

The ITER device is a long pulse tokamak with elongated plasma shape and single null poloidal divertor. The nominal inductive operation produces a Deuterium-Tritium fusion power of 500 MW for a burn duration of 400 to 3000 seconds, with the injection of 50 MW of auxiliary power. This provides a power gain of up to a factor of 10.

Safety and environmental characteristics of ITER reflect a consensus among the parties on safety principles and design criteria for minimizing the consequences of ITER operation on the public, operators and the environment. This consensus is supported by results of analysis on all postulated events and their consequences.

DOE will comply with all U.S. environmental and safety requirements applicable to the ITER work that will be conducted in the U.S. Compliance with the National Environmental Policy Act for the U.S. effort will be consistent with the standard DOE process and procedures in support of long-lead procurement for the manufacture of the components.

DOE's involvement with ITER at the international site will be consistent with a level of participation of about 10% as one of five non-host participants. In addition to scientists and engineers assigned to the ITER Organization, the U.S. expects to provide at least one senior management staff member to the ITER Organization. All U.S. personnel assigned to the project will comply with the environmental and safety requirements of the host country and with the applicable U.S. legal requirements.

As a result of the extensive collaborative efforts during the ITER Engineering Design Activities (EDA) from 1992 to 1998, and its extension from 1999 to 2001, a mature ITER design exists including completed R&D prototypes of critical ITER components.

First year funding is required in FY 2006 for the MIE for procurement of long lead hardware, for U.S. personnel assigned to the project abroad (the annual average number of engineers and scientists is ~22 FTEs as well as funding for support personnel at the international ITER site for ~34 FTEs), U.S. share of cash for ITER project common needs (ITER Organization infrastructure, installation and testing of U.S. supplied hardware), contingency, and operation of the U.S. ITER Project Office (responsible for management of U.S. Contributions to ITER including management, quality assurance, procurement, and technical follow of procurements).

The U.S. ITER Project Office, a partnership of Princeton Plasma Physics Laboratory (PPPL) and Oak Ridge National Laboratory, will manage the U.S. Contributions to ITER MIE: specifically the component procurements, provision of U.S. personnel joining the international legal entity managing the ITER project (the ITER Organization) abroad, and the provision of cash for common needs. DOE requires the U.S. ITER Project Office to assume a broad leadership role in the integration of ITER-related project activities throughout the U.S. fusion program and, as appropriate, internationally. For direct procurements with industry, the U.S. ITER Project Office is expected to rely upon experts throughout the fusion program for technical assistance in the execution of the procurements. Such experts, and their institutions, would become members of the U.S. ITER Project Office team although not necessarily located at the project office.

The U.S. ITER Project Office has the appropriate infrastructure and experience for the procurement and project management functions necessary to carry out this task in accordance with DOE Project Management Order 413.3, and also has extensive experience in the fusion energy sciences program.

The provisional list of U.S. hardware contributions, also called "in-kind" contributions to ITER, is indicated below. The ITER International Agreement is currently being negotiated and is expected to be completed by the end of FY 2005. The Agreement will finalize the current provisional list of equipment to be provided by each ITER Party and will finalize the mode of operation among the ITER Parties and central project team during the construction, operation and decommissioning phases of the ITER program.

- Niobium Tin (Nb3Sn) Superconducting Strand – Niobium, tin and copper filaments formed into long strands.
- Superconducting Cable - multi-stage cable including strand, insulation wraps and central spiral spring for cooling path.

- Central Solenoid Coil - the U.S. has the lead role for this contribution consisting of 4 of the 7 modules; and is responsible for module testing oversight and assembly oversight at the ITER site.
- Blanket Modules - a contribution consisting of 36 (of 360) modules around the tokamak vessel (plus 4 spares), 10% of the first wall area, 40 cm thick (including plasma facing components and shield).
- Vacuum Pumping Components - a U.S. contribution consisting of components required to create and maintain the vacuum inside the tokamak vessel.
- Tokamak Exhaust Processing System - a U.S. contribution to include recovery of hydrogen isotopes from impurities such as water and methane, delivery of purified, mixed hydrogen isotopes to the Isotope Separation System, and disposal of non-tritium species.
- Heating and Current-Drive Components for Ion Cyclotron Heating frequencies - the U.S. contribution includes High Voltage DC supplies, Radio Frequency Heating sources, and transmission lines, de-coupler, and tuning requirements.
- Heating and Current-Drive Components for Electron Cyclotron Heating frequencies - a U.S. contribution includes transmission lines, twenty-four DC power supplies, and three 1MW 120GHv gyrotrons.
- Fueling Injector - provides for an ITER pellet injector.
- Steady-state Electrical Power System - a U.S. contribution consisting of a steady-state electric power network similar in scale and function to an "auxiliary system" of a large power plant.
- Cooling Water System - the ITER tokamak water cooling systems is a U.S. contribution including the primary heat transfer system, the chemical and volume control system, and the draining, refilling and drying system.
- Diagnostics - a U.S. contribution involving 16% of the ITER Diagnostic effort providing six diagnostic systems such as visible and infrared cameras, toroidal interferometer/polarimeter, electron cyclotron emission, divertor interferometer, and residual gas analyzers; five cover plates on the tokamak vessel on which multiple diagnostics from U.S. and other parties are mounted; and integration of diagnostic systems from other ITER parties.

The preliminary schedule and TEC funding profile for the U.S. contributions to ITER MIE are as follows. The MIE project cost estimate for U.S. Contributions to ITER is preliminary until the Agreement is completed, following which the baseline scope, cost and schedule for the MIE project will be established. However, the overall TPC for this MIE project will not change with the exception of possible changes to the OMB-inflation rates that are in place at the time that the performance baseline is set, and changes in currency exchange rates affecting about 15% of the TPC funding.

U.S. Contributions to ITER

	Fiscal Quarter				Total Estimated Costs ($000)
	Procurements Initiated	Procurements Complete	Personnel Assignments to Foreign Site Start	Personnel Assignments to Foreign Site Complete	
FY 2006 Budget Request (Preliminary Estimate).................	3Q FY 2006	4Q FY 2012	2Q FY 2006	4Q FY 2013	1,038,000

Financial Schedule
Total Estimated Cost (TEC)

(budget authority in thousands)

Fiscal Year	MIE TEC
2006	46,000
2007	130,000
2008	182,000
2009	191,000
2010	189,000
2011	151,000
2012	120,000
2013	29,000
Total	1,038,000

Note, the Other Project Costs associated with these MIE TEC funds are budgeted in the Enabling R&D subprogram.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Plant Projects/General Purpose Equipment/Other	**3,217**	**3,176**	**3,276**

These funds provide primarily for general infrastructure repairs and upgrades for the PPPL site based upon quantitative analysis of safety requirements, equipment reliability and research needs. Funds also provide for the move of ORNL fusion personnel and facilities to a new location at ORNL.

Total, Facility Operations..	**85,690**	**89,943**	**127,519**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
DIII-D	
This decrease will result in curtailing or deferring some facility modifications and refurbishments and conducting 5 weeks of operation, a decrease of nine weeks from the FY 2005 planned operation..	-4,138

	FY 2006 vs. FY 2005 ($000)
Alcator C-Mod	
The decrease, when combined with increased costs for materials and services, will reduce the number of weeks of operation by five (compared to FY 2005) to 12 weeks.	-305
NSTX	
This decrease will eliminate operating time in FY 2006, a reduction of seventeen weeks compared to FY 2005 planned operations.	-3,534
NCSX	
This decrease will delay the procurement of some of the equipment for this MIE.	-1,600
GPP/GPE/Other	
This increase will allow continued improvement of the physical infrastructure at PPPL and continue the process of moving fusion personnel from the Y-12 site to the X-10 site at ORNL.	+100
ITER Preparations	
This increase allows final U.S. preparations for participation in the international ITER project to be completed during FY 2006, including additional funds for vendor qualification and project management preparations	+1,053
U.S. Contributions to ITER (MIE Total Estimated Cost)	
This funding initiates the TEC funding for the Major Item of Equipment project entitled U.S. Contributions to ITER..	+46,000
Total Funding Change, Facility Operations	**+37,576**

Enabling R&D

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Enabling R&D					
Engineering Research	19,817	21,574	16,760	-4,814	-22.3%
Materials Research	7,629	7,323	0	-7,323	-100.0%
Enabling R&D for ITER	0	0	3,500	+3,500	--
Total, Enabling R&D	27,446	28,897	20,260	-8,637	-29.9%

Description

The mission of the Enabling R&D subprogram is to develop the cutting edge technologies that enable both U.S. and international fusion research facilities to achieve their goals.

Benefits

The foremost benefit of this subprogram is that it enables the scientific advances in plasma physics accomplished within the Science subprogram. That is, the Enabling R&D subprogram develops, and continually improves, the hardware and systems that are incorporated into existing fusion research facilities, thereby enabling these facilities to achieve higher and higher levels of performance within their inherent capability. In addition, the Enabling R&D subprogram supports the development of new hardware that is incorporated into the design of next generation facilities, thereby increasing confidence that the predicted performance of these new facilities will be achieved. Finally, there is a broader benefit beyond the fusion program in that a number of the technological advances lead directly to "spin offs" in other fields, such as superconductivity, plasma processing and materials enhancements.

Supporting Information

The Engineering Research element addresses the breadth and diversity of domestic interests in enabling R&D for magnetic fusion systems as well as international collaborations that support the mission and objectives of the FES program. The activities in this element focus on critical technology needs for enabling both current and future U.S. plasma experiments to achieve their research goals and full performance potential in a safe manner, with emphasis on plasma heating, fueling, and surface protection technologies. While much of the effort is focused on current devices, a significant and increasing amount of the research is oriented toward the technology needs of future experiments, such as ITER. Enabling R&D efforts provide both evolutionary development advances in present day capabilities that will make it possible to enter new plasma experiment regimes, such as burning plasmas, and nearer-term technology advancements enabling international technology collaborations that allow the U.S. to access plasma experimental conditions not available domestically. A part of this element is oriented toward investigation of scientific issues for innovative technology concepts that could make revolutionary changes in the way that plasma experiments are conducted, such as liquid surface approaches to control plasma particle density and temperature, microwave generators with tunable frequencies and steerable launchers for fine control over plasma heating and current drive, and magnet technologies that could improve plasma confinement. This element includes research on tritium technologies that will be needed to produce, control, and process tritium for self-sufficiency in fuel supply. This element also supports research on safety-related issues that enables both current and future experiments to be conducted in an environmentally sound and safe manner. Another activity is conceptual design of the most scientifically challenging systems for fusion research facilities that may be needed in the future. Also included are analysis and studies of critical scientific and technological issues, the results of which will provide guidance for optimizing future experimental approaches and for understanding the implications of fusion research on applications of fusion.

For the Materials Research element, no activities will be conducted. The substantial international effort on fusion materials research will be monitored, as will the work on nanosystems and computational materials science funded by the Basic Energy Sciences program and other government-sponsored programs.

Management of the diverse and distributed collection of technology R&D activities continues to be accomplished through a Virtual Laboratory for Technology (VLT), with community-based coordination and communication of plans, progress, and results.

Research efforts will continue on the domestic plasma experiments and on the scientific foundations of innovative technology concepts for use in future experiments. Selected efforts will be redirected from the Engineering Research area to a new Enabling R&D for ITER category to concentrate on specific R&D supporting U.S. responsibilities for ITER procurement packages. In addition, some of these funds will be reoriented from the Materials Research area for R&D and design support in a number of areas, including magnets, plasma facing components, tritium processing, fueling and pumping, heating and current drive, and diagnostics, which support ITER.

Technology Accomplishments

A number of technological advances were made in FY 2004. Examples include:

- The electron cyclotron heating system on DIII-D tokamak at General Atomics was upgraded to 6 MW and was used in experimentation. A load tolerant prototype antenna was fabricated and successfully tested for the Joint European Torus program as part of the International Collaborations activity in the Science subprogram.
- PPPL completed a series of experiments in the Current Drive Experiment-Upgrade (CDX-U) to study the feasibility of liquid lithium surface plasma-facing components, which have the potential for higher surface heat and particle removal than solid surface components now in use. A toroidal tray near the bottom of the CDX-U was filled with liquid lithium, exposing plasma discharges to a large surface area of the liquid. With improvements made to achieving a high degree of surface cleanliness, substantial levels of particle removal took place and both plasma current and discharge duration were increased by 30% relative to discharges without the liquid lithium. The success of these experiments has provided the basis for decisions to develop lithium surface technology for NSTX, initially in the form of solid lithium coatings and eventually as a flowing liquid lithium module capable of highly efficient particle removal at high surface heat fluxes.
- The Safety and Tritium Applied Research (STAR) facility at the Idaho National Laboratory achieved full scale tritium operations capability. The STAR facility, which has been declared a National User Facility, provides a laboratory for fusion research pertaining to properties associated with tritium chemistry and material interactions. It also provides unique capabilities to conduct tritium safety experiments for current and future fusion facilities, such as ITER.
- The University of California, San Diego (UCSD), in collaboration with European laboratories, completed the first phase of experiments in the Plasma Interactive Surface Component Experimental Station (PISCES), a plasma edge simulation facility, to evaluate the potential for tritium accumulation in the ITER plasma chamber. Substantial accumulation of tritium in ITER could limit

its operating time if safety-related tritium inventory limits are reached. With its unique capability in the world to simulate the edge conditions of the ITER plasma with all of the materials to be used on the ITER plasma chamber (i.e., carbon, beryllium, and tungsten), experiments in the PISCES facility indicated that the presence of beryllium tends to suppress erosion of carbon surfaces, which could reduce tritium accumulation due to tritium bonding with carbon. The experiments are being used to identify means for mitigating formation of carbon deposits so that tritium accumulation will not be a major interference with ITER operation.

Detailed Justification

(dollars in thousands)	FY 2004	FY 2005	FY 2006
Engineering Research	**19,817**	**21,574**	**16,760**
▪ **Plasma Technology**	**13,615**	**18,411**	**14,200**

Engineering research efforts will continue on critical needs of domestic plasma experiments, on ITER R&D preparations and on the scientific foundations of innovative technology concepts for use in future experiments. In FY 2006, $3,500,000 is redirected to support the ITER OPC R&D efforts. Nearer-term experiment support efforts will be oriented toward plasma facing components and plasma heating and fueling technologies, while longer term efforts focus more on new concepts for surface heat and particle removal, tritium material science and safety research. During FY 2006, the following specific elements will be pursued:

- Testing of a super efficient (over 60 %) 110 gigahertz, 1.5 megawatt industrial prototype gyrotron microwave generator, the most powerful and efficient of its kind for electron cyclotron heating of plasmas, will be completed.
- Testing of a high speed, compact vertical pellet injector system relevant to the fueling requirements of next step experiments will also be completed.
- Based on the experimental research and initial designs during FY 2005 for a first-generation system that allows flowing lithium to interact directly with the plasma, potentially revolutionizing the approach to plasma particle density and edge temperature control in plasma experiments, the preliminary design of a lithium module for future deployment in NSTX will be completed during FY 2006.
- Studies will continue in the PISCES facility at the University of California at San Diego, and the Tritium Plasma Experiment at INL, of tungsten-carbon-beryllium mixed materials layer formation and redeposition with attached hydrogen isotopes, and results will be applied to evaluate tritium accumulation in plasma facing components.
- In the STAR facility at INL, the final series of material science experiments will be initiated under a cost-sharing collaboration with Japan to resolve key issues of tritium behavior in materials proposed for use in fusion systems.
- Additional funds will be provided for plasma chamber design and analysis, as well as for research on heat extraction and processing technologies for blanket concepts that will be tested in ITER.
- Funds will be provided for research on superconducting magnets, which can be used in future experiments.

	FY 2004	FY 2005	FY 2006

(dollars in thousands)

- Funds will also be provided for safety research, and innovative technology research in the area of plasma-surface interaction sciences that will enable fusion experimental facilities to achieve their major scientific research goals and full performance potential.

	FY 2004	FY 2005	FY 2006
▪ **Fusion Technology**	**3,038**	**0**	**0**

The final year of funding for Fusion Technology efforts was FY 2004 in order to focus on research relevant to ITER. No activities are planned for FY 2005 and FY 2006.

	FY 2004	FY 2005	FY 2006
▪ **Advanced Design**	**3,164**	**3,163**	**2,560**

Funding for this effort will continue to focus on studies of compact stellarators. Systems studies to assess both the research needs underlying achievement of the safety, economics, and environmental characteristics of such advanced magnetic confinement concepts will be conducted in an iterative fashion with the experimental community.

	FY 2004	FY 2005	FY 2006
Materials Research	**7,629**	**7,323**	**0**

Materials Research efforts, which were focused on long-term development of structural materials for the chambers of fusion energy systems that might be constructed beyond ITER, are being terminated to provide resources for higher priority and nearer term activities.

	FY 2004	FY 2005	FY 2006
Enabling R&D for ITER (Other Project Costs)	**0**	**0**	**3,500**

Enabling R&D funds for ITER activities are identified in FY 2006 for the start of the U.S. Contributions to ITER MIE. Funds are needed for R&D and design in support of equipment in a number of areas including magnets R&D and design, plasma facing components, tritium processing, fueling and pumping, heating and current drive, materials, and diagnostics, which would be provided by the U.S. to ITER. The results of this R&D and design are also broadly applicable to future burning plasma experiments. These activities are directly associated with the ongoing base program and while they will be carried out by scientists and technologists as part of their ongoing efforts, once reorientation to ITER has been accomplished, these activities will be managed using DOE Order 413.3 project management tools for controlling schedule, cost and scope.

It is important to note that the ITER International Agreement is currently being negotiated and is expected to be completed by the end of FY 2005. The Agreement will finalize the current provisional list of equipment to be provided by each ITER Party and will finalize the mode of operation among the ITER Parties and central project team during the construction, operation and decommissioning phases of the ITER program. The MIE project cost estimates for U.S. Contributions to ITER, including the Other Project Cost activities, are preliminary until the Agreement is completed, following which the baseline scope, cost and schedule for the MIE project will be established. However, the overall TPC for this MIE project will not change with the exception of possible changes to the OMB-inflation rates that are in place at the time that the performance baseline is set, and changes in currency exchange rates affecting about 15% of the TPC funding.

For the most part, these activities will be accomplished by focusing these same scientists and technologists on specific ITER tasks in a project mode. Based on the funding profile for these activities shown below, additional funds will be required for FY 2007-2009 in this subprogram. During FY 2006, the following specific elements will be pursued:

	(dollars in thousands)	
FY 2004	FY 2005	FY 2006

- Conduct R&D to support fabrication and final design of the first wall shield module for ITER.
- Conduct R&D to support qualification for manufacturing superconducting strand and jacket material for the ITER Central Solenoid.
- Conduct R&D to support design of two key systems, the high throughput continuous extruder and centrifuge accelerator, of the ITER Pellet Injector.
- Conduct R&D to support design of the ITER Fuel Cleanup System and develop a dynamic process modeling code of the ITER tritium system.
- Conduct R&D to support design of the ITER heating antenna.
- Conduct R&D to support fabrication of the ITER 1 MW, 120 GHz start-up gyrotron.
- Conduct R&D to support selection of different materials and components necessary for ITER diagnostics

U.S. Contributions to ITER
Financial Schedule
Other Project Costs (OPC)

(budget authority in thousands)

Fiscal Year	Other Project Costs
2006	3,500
2007	16,000
2008	18,800
2009	16,500
2010	10,300
2011	9,300
2012	6,200
2013	3,400
Total	84,000

Note, the MIE TEC funding associated with these Other Project Costs is budgeted in the Facility Operations subprogram.

	FY 2004	FY 2005	FY 2006
Total, Enabling R&D	**27,446**	**28,897**	**20,260**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Engineering Research	
▪ **Plasma Technology**	
This decrease reflects a $3,500,000 redirection to R&D for ITER (MIE OPC) for efforts in magnets, plasma facing components, heating and fueling technologies, and a $711,000 reduction in a number of research areas including test blankets, tritium technology, safety, plasma facing components, heating and neutronics.	-4,211
▪ **Advanced Design**	
This decrease reflects the shift of the next step options program to more direct support of ITER R&D needs, and a slight reduction in support for the management of the Virtual Laboratory for Technology.	-603
Total, Engineering Research	**-4,814**
Materials Research	
Materials Research, which generally consists of longer range materials activities, will be terminated in FY 2005 and no activities are planned for FY 2006.	-7,323
Enabling R&D for ITER (MIE Other Project Costs)	
Funding is redirected from Plasma Technology to focus efforts in support of ITER in the magnet, plasma facing components, tritium processing, fueling and pumping, heating and current drive, materials and diagnostics areas.	+3,500
Total Funding Change, Enabling R&D	**-8,637**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	1,735	1,643	1,810	+167	+10.2%
Capital Equipment	23,229	23,488	65,504	+42,016	+178.9%
Total, Capital Operating Expenses	24,964	25,131	67,314	+42,183	+167.9%

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

(dollars in thousands)

	Total Project Cost (TPC)	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Acceptance Date
NCSX	103,251	90,839	7,897	15,921	17,500	15,900	FY 2009[a]
U.S. Contributions to ITER	1,122,000[b]	1,038,000[b]	0	0	0	46,000	FY 2013
Total, Major Items of Equipment				15,921	17,500	61,900	

[a] The FY 2005 Congressional budget reflected an estimated TEC range for NCSX of $87,000,000 - $89,000,000 with a completion range of FY 2008-FY 2009. The current estimated TEC is $90,839,000 with completion in May 2009. A new cost and schedule performance baseline will be developed in mid-FY 2005.

[b] Funding initiates Major Item of Equipment project, U.S. Contributions to ITER. These figures are preliminary estimates, though the TPC for U.S. Contributions to ITER would change only if OMB-established inflation rates change between now and when the performance baseline for scope, cost, and schedule is established after the ITER International Agreement is completed, and if currency exchange rates change affecting about 15% of the TPC funding. The estimates have been prepared based upon (1) U.S. industrial estimates for the hardware items the United States is likely to contribute, (2) OFES estimates for personnel to be assigned abroad consistent with previous experience during the ITER Engineering Design Activities, (3) U.S. cash contributions for a 10% participant in the ITER project, and (4) OFES estimates for operation of the U.S. ITER Project Office including technical oversight of procurement.

Science Laboratories Infrastructure

Funding Profile by Subprogram

	(dollars in thousands)				
	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Science Laboratories Infrastructure					
Laboratories Facilities Support	34,256	26,157	-209[a]	25,948	20,389
Excess Facilities Disposition	6,020	6,100	-49[a]	6,051	14,637
Oak Ridge Landlord	5,049	5,079	-40[a]	5,039	5,079
Health & Safety Improvements	9,941	5,000	-40[a]	4,960	0
Total, Science Laboratories Infrastructure	55,266[b]	42,336	-338	41,998	40,105

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

Mission

The mission of the Science Laboratories Infrastructure (SLI) program is to enable the conduct of Departmental research missions at the ten Office of Science (SC) laboratories and the Oak Ridge Institute for Science and Education (ORISE) by funding line item construction and general plant projects to maintain the general purpose infrastructure (GPI) and the clean-up and removal of excess facilities. The program also supports SC landlord responsibilities for over 24,000 acres of the Oak Ridge Reservation (ORR); provides Payment in Lieu of Taxes (PILT) to local communities around Argonne National Laboratory-East (ANL-E), Brookhaven National Laboratory (BNL), and Oak Ridge National Laboratory (ORNL); and provides for the correction of Occupational Safety & Health Administration (OSHA) and Nuclear Regulatory Commission (NRC) identified deficiencies and implementation of recommendations for improved health and safety practices at SC laboratories.

Benefits

This program supports the conduct of Departmental research missions at the ten SC laboratories and the ORR, including the Federal facilities in the town of Oak Ridge, primarily by addressing general purpose facilities and infrastructures needs.

Significant Program Shifts

Progress in Line Item Projects – Six subprojects were completed in FY 2004: BNL Groundwater and Surface Water Protection Upgrades; BNL Electrical Systems Modifications, Phase II; LBNL Site-wide Water Distribution System Upgrades; ORNL Laboratory Facilities HVAC Upgrade; ORNL Fire Protection Systems Upgrades; and the ANL-E Fire Safety Improvements, Phase IV. In FY 2005, two

[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes a reduction of $310,000 in accordance with P.L. 108-137, the Consolidated Appropriations Act, 2004.

subprojects are scheduled for completion: ORNL Research Support Center; and the ANL-E Mechanical and Control Systems Upgrades-PH I.

Funding of $3,000,000 is requested under the Laboratories Facilities Support subprogram to support continued design of the Pacific Northwest National Laboratory (PNNL) Capabilities Replacement Laboratory project (MEL-001-046). This candidate project would help replace SC-related research capabilities—should a thorough alternatives analysis demonstrate a need for their replacement—currently performed in the Hanford 300 Area that will be lost due to the closure and clean-up of the 300 Area by the Office of Environmental Management (EM). Under the current EM schedule, PNNL staff must vacate the 300 Area by the end of FY 2009.

Funding of $11,046,000 is requested under the Excess Facilities Disposition (EFD) subprogram to initiate a decontamination and decommissioning (D&D) of the Bevatron Complex at the Lawrence Berkeley National Laboratory (LBNL).

In FY 2006, General Plant Projects (GPP) funding is requested to refurbish and rehabilitate the general purpose infrastructure necessary to perform cutting edge research throughout the SC laboratory complex.

No funding is requested under the Health and Safety Improvements subprogram to continue health and safety improvements at SC laboratories identified in the OSHA and NRC reviews. Previous funding is deemed sufficient to address the most significant health and safety issues. If the Administration determines that health and safety issues remain, resources will be requested in future years as necessary.

Conference report language accompanying the FY 2005 appropriation indicated that $5,000,000 would be redirected from SLI construction funds at Stanford Linear Accelerator (SLAC) MEL-001 subproject 36 to the High Energy Physics program for the research program at SLAC. Accordingly, $5,000,000 is held for possible reprogramming in FY 2005 with funding for the SLAC project in the MEL-001 project data sheet commensurately reduced.

Laboratories Facilities Support

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Laboratory Facilities Support					
General Purpose Facilities	25,605	22,168	10,426	-11,742	-53.0%
Environment, Safety and Health	7,140	2,028	5,443	+3,415	+168.4%
Payment in Lieu of Taxes (PILT)	1,511	1,752	1,520	-232	-13.2%
General Plant Projects (GPP)	0	0	3,000	+3,000	--
Total, Laboratories Facilities Support	34,256	25,948	20,389	-5,559	-21.4%

Description

The Laboratories Facilities Support (LFS) subprogram improves the mission readiness of Office of Science (SC) laboratories by funding line item construction projects to refurbish or replace general purpose facilities and the site-wide infrastructure.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from subprograms which support the GPRA Units in carrying out their mission. The SLI program performs the following functions in support of the overall SC mission: providing line item construction and general plant projects to maintain the general purpose infrastructure, the clean-up and removal of excess facilities, the support of landlord responsibilities for the Oak Ridge Reservation in Tennessee, correction of safety deficiencies identified by OSHA and NRC, and the Payment in Lieu of Taxes (PILT) to local communities around Argonne, Brookhaven, and Oak Ridge national laboratories.

Benefits

This subprogram improves the mission readiness of SC laboratories by funding line item construction projects that refurbish or replace general purpose facilities and site-wide infrastructure. The subprogram also provides PILT assistance as required by law for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory.

Supporting Information

General purpose and site-wide infrastructure includes administrative, research laboratory, user support and testing space as well as cafeterias, power plants, fire stations, electrical, gas and other utility distribution systems, sanitary sewers, roads, and other associated structures. The 10 SC laboratories have 2,382 buildings (including 802 trailers and 152 excess buildings) with a total square footage of over 20,000,000 square feet. The LFS subprogram also provides PILT assistance for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory.

Capital investment requirements for SC laboratories are identified in laboratory strategic facilities plans. These plans assume the full modernization/revitalization of the infrastructure of the laboratories will be completed over a ten-year period and include priority lists of proposed facilities and infrastructure needs. The backlog of line item construction and GPP modernization needs as summarized in SC’s 2003

Update of the “Infrastructure Frontier Report: A Quick Look Survey of the Office of Science Laboratory Infrastructure,” is on the order of $2 billion. Nearly 85% of this total is to rehabilitate or replace buildings.

The large backlog of construction needs is attributable to:

- the age of the facilities (over 57% of the buildings are 30 years old or older, and 36% are 40 years old or older);
- the use of wood and other non-permanent building materials in the original construction of the laboratories in the 40’s and 50’s;
- changing research needs that require:
  - different kinds of space (e.g., nuclear facilities including hot cells are in less demand while facilities that foster interaction and team-based research are in high demand); and
  - higher quality of space (e.g., reduced vibration sensitivity and temperature variability, and increased air quality and power demand for computers and other electronic equipment);
- obsolescence of existing building systems and components and changing technology (e.g., digital controls for heating and ventilation systems, fire alarms, security);
- increased requirements for continuity of utility operations to support large user population at SC user research facilities; and
- changing environmental, safety and health regulations and security needs.

All candidate construction subprojects for funding by the LFS subprogram are scored using the DOE Cost-Risk-Impact Matrix that takes into account risk, impacts, and mission need. The subprojects that have ES&H as the principal driver are further prioritized using the Risk Prioritization Model from the DOE ES&H and Infrastructure Management Plan process. Based on these scores, the LFS subprogram prioritizes the subprojects. The prioritized list is further evaluated for SC science program mission impact by an integrated infrastructure management team composed of the LFS subprogram and SC research program offices. Subprojects are then proposed from this list consistent with budget availability.

The LFS subprogram ensures that the funded subprojects are managed effectively and completed within the established cost, scope and schedule baselines. Performance will be measured by the number of all SLI subprojects completed within the approved baseline for cost, scope (within 10%), and schedule (within six months). Of the six subprojects completed in FY 2004, five were completed within their cost, scope and schedule baselines; one required a five month schedule extension, but did complete its scope within cost.

SLI construction subprojects are typical conventional construction and as such can be engineered, designed and ready for construction contract award within one fiscal year, or in the following fiscal year. Accordingly, SLI construction subprojects are submitted with both Project Engineering and Design (PED) and construction funding identified. In most cases these subprojects proceed (after normal reviews and approvals) directly from design into construction with no delay. DOE's December 2000 Report to Congress, “The US DOE Implementation Procedures for the Use of External Independent Reviews and Project Engineering and Design Funds,” allows this approach under the Section

"Simplified Process for a Design-Procure-Build or Design-Build Project," pages 15 to 18. The full report can be found at the following web site: http://www.sc.doe.gov/sc-80/sc-82/docs.html.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Purpose Facilities	**25,605**	**22,168**	**10,426**

Provides funding to support the continuation of three on-going subprojects under the Science Laboratories Infrastructure Project Engineering and Design (PED) data sheet and construction project data sheet. These projects are identified below. More details are provided in the data sheets presented later. FY 2005 funding includes $5,000,000 held for a possible reprogramming to the HEP program for the research program at SLAC in accordance with conference report direction.

Ongoing :

- LBNL Building 77 Rehabilitation of Structures and Systems, Phase II ($3,780,000)
- BNL Research Support Building, Phase I ($3,646,000)
- PNNL Capability Replacement Laboratory ($3,000,000)

Environment, Safety and Health	**7,140**	**2,028**	**5,443**

Provides funding to support the continuation of one subproject under the Science Laboratories Infrastructure construction project data sheet (MEL-001).

Ongoing:

- SLAC Safety and Operational Reliability Improvements ($5,443,000)

General Plant Projects (GPP)	**0**	**0**	**3,000**

Provides funding for GPP Construction projects (Total Estimated Cost less than $5,000,000) to refurbish and rehabilitate general purpose infrastructure necessary to perform cutting edge research throughout the SC Laboratory complex.

Payment in Lieu of Taxes (PILT)	**1,511**	**1,752**	**1,520**

Provide PILT to support assistance requirements for communities surrounding Brookhaven National Laboratory and Argonne National Laboratory. PILT payments are negotiated between the Department and local governments based on land values and tax rates.

Total, Laboratories Facilities Support	**34,256**	**25,948**	**20,389**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
General Purpose Facilities (GPF)	
▪ Reduction due primarily to the normal project funding roll off from completed projects. Also, the funding pace of the PNNL Capability Replacement Laboratories was slowed pending development of more detail on the size and nature of the planned replacement structure.	-11,742
Environmental Safety & Health (ES&H)	
▪ Increased funding for the SLAC Safety and Operational Reliability Improvements subproject reflects the normal ramp-up per the construction funding plan	+3,415
PILT	
▪ Reduction due to offsetting payments from other federal agencies.	-232
GPP	
▪ Initiates funding of GPP projects.	+3,000
Total Funding Change, Laboratories Facilities Support	**-5,559**

Excess Facilities Disposition

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Excess Facilities Disposition	6,020	6,051	14,637	+8,586	+141.9%

Description

The Excess Facilities Disposition (EFD) subprogram removes excess facilities at the SC laboratories to reduce long-term costs and liabilities in support of programmatic initiatives (e.g., making land available for new programs). In addition to removal of excess facilities, the subprogram also cleans-up facilities for reuse when such reuse is economical and provides needed functionality.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from subprograms which support the GPRA Units in carrying out their mission. The SLI program performs the following functions in support of the overall SC mission: providing line item construction and general plant projects to maintain the general purpose infrastructure, the clean-up and removal of excess facilities, the support of landlord responsibilities for the Oak Ridge Reservation in Tennessee, correction of safety deficiencies identified by OSHA and NRC, and the Payment in Lieu of Taxes to local communities around Argonne, Brookhaven, and Oak Ridge national laboratories.

Benefits

This subprogram reduces the long-term costs, risks and liabilities at the SC laboratories associated with excess facilities by removing them or cleaning them up for reuse or transfer. It also supports programmatic initiatives by making land available for new programs and reducing expenditures on surveillance and maintenance of excess facilities.

Supporting Information

The EFD subprogram evaluates and prioritizes the backlog based on footprint reduction, risk reduction (e.g., removal of hazards), availability of space/land for research activities, and cost savings (e.g., elimination of surveillance and maintenance costs). The prioritized list is further evaluated for mission impact by an integrated infrastructure management team representing the EFD subprogram and SC research program offices. The estimated backlog of non-contaminated or slightly contaminated facilities at the beginning of FY 2006 will be approximately $14,000,000.

In FY 2006, the EFD subprogram will accelerate decontamination and decommissioning (D&D) of the Bevatron Complex at the Lawrence Berkeley National Laboratory (LBNL). This effort, whose cost is estimated to range from $67 million to $83 million, will eliminate a legacy facility which ceased operation in 1993, and free up approximately 7.5% of the total usable land at the LBNL site for programmatic use. This project will be carried out over a 5-6 year period beginning in FY 2006.

Both laboratory and office space are in critically short supply at LBNL. The shortage of onsite space has necessitated leasing of approximately 95,000 square feet in offsite buildings. Continued reliance on an aged and decaying physical plant impedes research, reduces productivity, and makes recruitment and retention of top-quality scientists and engineers much more difficult. Removal of the Bevatron will free up land for re-development to support on-going and new mission work.

The EFD subprogram will also demolish contaminated, legacy facilities at Brookhaven National Laboratory (BNL), Oak Ridge National Laboratory (ORNL) and the Oak Ridge Institute for Science and Education (ORISE), whose continued deterioration presents an increasing risk to the workers and the environment, and for which SC can "bank" space to meet the requirement for offsetting new construction with elimination of excess space. These facilities include Building 650 at BNL, Building 2000 at ORNL and Building SC-5 at ORISE.

The EFD subprogram does not fund projects that replace currently active and occupied buildings (e.g., old, deteriorated and marginally functional ones that are still used but are to be replaced by new, modern buildings). Such building replacement projects are funded under the previously described LFS subprogram and would include removal of the old buildings as part of the justification for the project.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Excess Facilities Disposition	**6,020**	**6,051**	**14,637**

In FY 2004, funding of $6,020,000 supported the 18 projects listed below and allowed for the clean-up/removal of an estimated 103,000 square feet of space:

- Ames ($150,000) – Waste Handling Facility Closeout and Demolition, Phase 1
- ANL-E ($979,000) – Building 202 (Kennels) Partial Disposal, Building 202, D-149 Lead Vault Demolition, Building 205 G101 Remediation, Building 317 Bailer Building Demolition, and Building 329 Demolition (approximately 6,500 sq. ft.)
- BNL ($993,000) – Demolition of Buildings 206/207/208/457/458, Demolition of Building 88 and Demolition of Building 919F (approximately 43,000 sq. ft.)
- FNAL ($233,000) – Bubble Chamber Demolition (approximately 3,000 sq. ft.)
- LBNL ($1,525,000) – Removal of Upper Layer Roof Concrete Shielding Blocks & Beamline Components, Removal of Shielding Blocks, Beamlines, Three Transportainers and Lead Dust Filters and Fan Equipment from Building 51 of the Bevatron Complex, and Demolition of Building 29D (approximately 2,000 sq. ft.).
- LLNL ($250,000) – Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase 1 (approximately 8,000 sq. ft.)
- ORNL ($760,000) – Demolition of Buildings 2069/7010/2016/7055 and Demolition of Building 5000 (approximately 19,000 sq. ft.)
- PPPL ($980,000) – Princeton Beta Experiment Modification (PBX)/Princeton Large Torus (PLT) Final Subsystem Removals and Cooling Tower Demolition (approximately 18,200 sq. ft.)
- SLAC ($150,000) – B Target Room (End Station B Building) Cleanout (approximately 3,000 sq. ft.)

	(dollars in thousands)	
FY 2004	FY 2005	FY 2006

In FY 2005, funding of $6,051,000 will support the 19 projects listed below and allow for the clean-up/removal of an estimated 63,000 square feet of space:

- Ames ($150,000) – Waste Handling Facility Closeout and Demolition, Phase 2 (approximately 9,000 sq. ft.)
- ANL-E ($1,235,000) – Bldg. 202, Room Q-183 Former Animal Injection Laboratory Remediation, Bldg. 202, W-Wing (W-036, W-123, W-127, W-135) Demolition, Bldg. 370 Alkali Metal Loop Demolition, Bldg. 40 Demolition, Phase 1, and Bldg. 205 K-116 Remediation (approximately 6,500 sq. ft.)
- BNL ($405,000) – Demolition of Buildings 527, 492, 933B, 650A and 934, and Partial Demolition of Buildings 197 and 422 (approximately 10,000 sq. ft.)
- FNAL ($125,000) – Demolition of Two Muon Enclosures (approximately 800 sq. ft.)
- LBNL ($1,360,000) – Development of Conceptual Design, Environmental and CD-1 Documentation for the Bevatron Disposition Project
- LLNL ($150,000) – Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase 2
- ORISE ($565,000) – Demolition of Building SC-2, Isotope Laboratory (approximately 1,000 sq. ft.)
- ORNL ($1,679,000) – Demolition of Buildings 2001 and 2024 (approximately 36,000 sq. ft.)
- Unallocated ($382,000) – To be allocated to other priority projects in FY 2005.

In FY 2006, funding of $14,637,000 will support the 10 projects listed below and allow for the clean-up/removal of an estimated 79,000 square feet of space:

- Ames ($45,000) – Demolition of Hydrogen Test Cell Facility (900 sq. ft.)
- ANL-E ($770,000) – Bldg. 200 Heavy Isotopes Hood/Equipment Demolition and Bldg. 205 F-111 Excess/Contaminated Media and Equipment Clean-up (Phase 2) (approximately 3,100 sq. ft.)
- BNL ($600,000) – Demolition of Building 86 and Demolition of Building 650, Phase 1 (approximately 11,000 sq. ft.)
- FNAL ($125,000) – Demolition of Two Muon Enclosures (approximately 800 sq. ft.)
- LBNL ($11,046,000) – This funding will support removal of Building 51A of the Bevatron complex, a 28,478 square foot high bay structure. It will also support activities required to execute total removal of the Building 51/ Bevatron complex, including: surveys and planning activities, such as engineered plans and specifications for the demolition of the Bevatron and Building 51; waste management plan; characterization plan; health & safety plan; and community relations plan. The FY 2006 funding will also support utility relocations, preliminary hazardous material abatement, and removal of abandoned electrical equipment. (approximately 28,000 sq. ft.)
- LLNL ($150,000) – Demolition of Magnetic Fusion Energy Legacy Facilities at Building 445, Phase 3 (approximately 7,000 sq. ft.)

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- ORISE ($768,000) – Demolition of Building SC-5, Large Animal Containment Facility (approximately 5,600 sq. ft.)
- ORNL ($1,133,000) – Demolition of Building 2000 (approximately 23,000 sq. ft.)

Individual projects and amounts are subject to revision based on evolving program priorities including risk reduction (e.g., removal of hazards), footprint reduction, cost savings (e.g., elimination of surveillance and maintenance costs), and availability of space/land for new research activities.

	FY 2004	FY 2005	FY 2006
Total, Excess Facilities Disposition	**6,020**	**6,051**	**14,637**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Excess Facilities Disposition	
▪ Increase to support a more aggressive D&D of the LBNL Bevatron Complex.	+8,586

Oak Ridge Landlord

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Oak Ridge Landlord	5,049	5,039	5,079	+$40	+0.8%

Description

The Oak Ridge Landlord subprogram supports activities to maintain continuity of operations at the Oak Ridge Reservation (ORR) and the Oak Ridge Operations Office (ORO).

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from subprograms which support the GPRA Units in carrying out their mission. The SLI program performs the following functions in support of the overall SC mission: providing line item construction and general plant projects to maintain the general purpose infrastructure, the clean-up and removal of excess facilities, the support of landlord responsibilities for the Oak Ridge Reservation in Tennessee, correction of safety deficiencies identified by OSHA and NRC, and the Payment in Lieu of Taxes to local communities around Argonne, Brookhaven, and Oak Ridge national laboratories.

Benefits

This subprogram maintains continuity of operations at the Oak Ridge Reservation and the Oak Ridge Operations Office by minimizing interruptions due to infrastructure and/or other systems failures. The subprogram also provides Payment in Lieu of Taxes (PILT) assistance as required by law for communities surrounding Oak Ridge.

Supporting Information

The subprogram supports landlord responsibilities, including infrastructure for the 24,000 acres of the ORR outside of the Y-12 plant, ORNL, and the East Tennessee Technology Park, plus DOE facilities in the town of Oak Ridge. This includes roads and grounds and other infrastructure maintenance, Environment, Safety and Health (ES&H) support and improvements, PILT for Oak Ridge communities, and other needs related to landlord requirements. These activities maintain continuity of operations at the Oak Ridge Reservation and the ORO and minimize interruptions due to infrastructure and/or other systems failures.

Detailed Justification

(dollars in thousands)

	FY 2004	FY 2005	FY 2006
Roads, Grounds and Other Infrastructure and ES&H Support and Improvements	**2,458**	**1,562**	**2,051**
Road maintenance, reservation mowing, and bridge inspections.			
General Purpose Equipment	**0**	**150**	**0**

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
General Plant Projects	**0**	**736**	**200**
Major road repair.			
Payment in Lieu of Taxes (PILT)	**2,300**	**2,300**	**2,550**
PILT to the City of Oak Ridge, and Anderson and Roane Counties.			
Reservation Technical Support	**291**	**291**	**278**
Includes meteorological monitoring system, public warning siren system, ORR command media, and records management.			
Total, Oak Ridge Landlord	**5,049**	**5,039**	**5,079**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Oak Ridge Landlord	
▪ Increase is to address maintenance needs.	+40

Health and Safety Improvement

Funding Schedule by Activity

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Health and Safety Improvement..........................	9,941	4,960	0	-4,960	-100%

Description

The Health and Safety Improvements subprogram corrects health and safety deficiencies at SC laboratories to ensure consistency with Occupational Safety and Health Administration (OSHA) and Nuclear Regulatory Commission (NRC) requirements.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from subprograms which support the GPRA Units in carrying out their mission. The SLI program performs the following functions in support of the overall SC mission: providing line item construction and general plant projects to maintain the general purpose infrastructure, the clean-up and removal of excess facilities, the support of landlord responsibilities for the Oak Ridge Reservation in Tennessee, correction of safety deficiencies identified by OSHA and NRC, and the Payment in Lieu of Taxes to local communities around Argonne, Brookhaven, and Oak Ridge national laboratories.

Benefits

This subprogram improves health and safety practices at SC laboratories to ensure consistency with Occupational Safety and Health Administration and Nuclear Regulatory Commission safety requirements.

In FY 2003, Congress directed the OSHA and NRC to perform inspections at the 10 SC laboratories. The purpose of these inspections was to document those deficiencies that would be identified if the Department were regulated by the OSHA and NRC, and to provide recommendations for improved health and safety practices.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Health and Safety Improvements	**9,941**	**4,960**	**0**

Funding corrected deficiencies at SC laboratories including: electrical hazards, machine guarding, legacy material removal, material handling, ladder compliance, inadequate building egress, crane hazards, exhaust ventilation, and eyewash station availability and operability.

Explanation of Funding Change

	FY 2006 vs. FY 2005 ($000)
Health and Safety Improvements	
▪ It is expected that the FY 2004 and FY 2005 funding will address the most significant health and safety issues at the laboratories. If the Administration determines that health and safety issues remain, resources will be requested in future years as necessary.	-4,960

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	100	736	3,200	+2,464	+334.8%
Capital Equipment	0	150	0	-150	-100.0%
Total, Capital Operating Expenses	0	886	3,200	+2,314	+261.2%

Construction Projects

(dollars in thousands)

	Total Estimated Cost (TEC)	Prior Year Appro-priations	FY 2004	FY 2005	FY 2006	Unapprop. Balance
Project – 04-SC-001 Science Laboratories Infrastructure Project						
FY 2004 PED Datasheet	N/A	N/A	2,974	4,960	3,000	0
Project - MEL-001 Science Laboratories Infrastructure Project						
FY 2006 Construction Datasheet	N/A	N/A	29,771	19,236	12,869	6,141
Total, Construction			32,745	24,196	15,869	6,141

Science Program Direction

Funding Profile by Subprogram

(dollars in thousands/whole FTEs)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Science Program Direction					
Program Direction	66,258	65,927	-1,030[abc]	64,897	70,132
Field Operations	84,019	89,341	-532[ab]	88,809	92,593
Total, Science Program Direction	150,277[d]	155,268	-1,562	153,706	162,725
Staffing (FTEs)					
Program Direction (FTEs)	315	344	3[b]	347	349
Field Operations (FTEs)	604	660	-3[b]	657	650
Total, FTEs	919[e]	1,004[e]	0	1,004[e]	999[e]

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

Mission

The mission of Science Program Direction (SCPD) is to provide a Federal workforce, skilled and highly motivated, to manage and support basic energy-related and science-related research disciplines, diversely supported through research programs, projects, and facilities under the Office of Science's (SC's) leadership.

SCPD consists of two subprograms: Program Direction and Field Operations. The Program Direction subprogram is the single funding source for the SC Federal staff in headquarters responsible for managing, directing, administering, and supporting the broad spectrum of SC scientific disciplines. This subprogram includes planning and analysis activities, providing the capabilities needed to evaluate and communicate the scientific excellence, relevance, and performance of SC basic research programs. Additionally, Program Direction includes funding for the Office of Scientific and Technical Information (OSTI), which collects, preserves, and disseminates research and development (R&D) information of the Department of Energy (DOE) for use by DOE, the scientific community, academia, U.S. industry, and the public to expand the knowledge base of science and technology. The Field Operations

[a] Includes a reduction for a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005, as follows: Program Direction ($-523,000); and Field Operations ($-714,000).
[b] Includes a reallocation of funding in accordance with H.Rpt. 108-792, accompanying P.L. 108-447, as follows: Program Direction ($-182,000, +3 FTEs) and Field Operations ($+182,000, -3 FTEs).
[c] Includes a reduction of $325,000 for a comparability adjustment for FY 2006 savings from the A-76 Financial Services competition that are transferred to Departmental Administration.
[d] Includes reductions of $864,000 rescinded in accordance with P.L. 108-137, the Consolidated Appropriations Act, 2004, and $313,000 for a comparability adjustment for FY 2006 savings from the A-76 Financial Services competition that were transferred to Departmental Administration.
[e] Reflects actual FTE usage for FY 2004 and approved FTE ceiling for FY 2005 and FY 2006.

subprogram is the centralized funding source for the Federal workforce within our field complex responsible for program implementation (Site Offices located at SC laboratories) and for providing best-in-class business, administrative, and specialized technical support across the entire SC enterprise and to other DOE programs the Integrated Support Center (ISC), operated in partnership by the Chicago and Oak Ridge Offices.

As stated in the Departmental Strategic Plan, DOE's Strategic and General Goals will be accomplished not only through the efforts of the major program offices in the Department but with additional effort from offices which support the programs in carrying out the mission. SCPD performs critical functions which directly support the mission of the Department. These functions include providing and supporting a workforce capable of delivering the remarkable discoveries and scientific tools that transform our understanding of energy and matter and advance the national, economic and energy security of the United States.

Significant Program Shifts

- The FY 2006 SCPD budget request reflects a moderate increase over the FY 2005 appropriation. The FY 2006 SCPD budget request will improve management flexibility, enhancing SC's ability to hire and retain technically skilled and expert staff to ensure sound program, project, financial and administrative management of the SC programs. Realignment of roles and responsibilities within the Department has increased SC's management and workload responsibility. The closure of the Oakland Operations Office by the National Nuclear Security Administration (NNSA) and standup of the Pacific Northwest Site Office during FY 2004 has and will continue to require significant SC resources in the financial, contracts, environmental, safety and health (ES&H) and safeguards and security (S&S) areas. The FY 2006 SCPD budget request will enable SC to fully support the workforce, provide management flexibility to develop and use innovative strategies to recruit and retain the most skilled and technically qualified employees, and meet increased management and workload burdens.
- Rollout of Phase 1 of the SC restructuring initiative (OneSC) was announced in March 2004. The new SC structure improves organizational and functional alignment, and reporting relationships by reducing layers of management, streamlining decision-making processes, clarifying lines of authority, and making better use of resources. A clear set of integrated roles, responsibilities, authorities, and accountabilities encompass the headquarters organization, site offices and the ISC. The ISC is comprised of the combined support capabilities of the Chicago and Oak Ridge Offices.
- Phase 2 of OneSC will occur over the next 24 months and involves human capital and organizational needs analyses and reengineering of SC business and management operations and processes. This phase will optimize SC business practices, take unnecessary work out of the system, enable the federal workforce to be more productive, support improved laboratory contractor performance, and ultimately drive down the cost of doing business in both federal and contractor operations. This effort embraces the changes envisioned by the President's Management Agenda (PMA) to manage government programs more economically and effectively.
- Attrition, retraining, and reassignments will be utilized in order to manage changes in staffing levels or skill mix needs resulting from Phase 2 activities. No downgrades, involuntary geographical transfers, separations, or reductions-in-force are planned or expected. In addition, enhanced recruitment, relocation, and retention bonuses authorized by the recently enacted Federal Workforce Flexibility Act of 2004 will be strategically employed to attract and retain technically skilled and highly qualified employees.

- Attrition in OSTI during FY 2004 resulted in 12 vacancies that will not be filled. The savings realized have been re-directed into contract support. This approach reflects the continued shift to performance of development and maintenance responsibilities by contractors rather than federal staff as identified in the expected near-term results in the Government-wide Initiative of Strategic Management of Human Capital in the PMA. *"Agencies will determine their 'core competencies' and decide whether to build internal capacity, or contract for services from the private sector. This will maximize agencies' flexibility in getting the job done effectively and efficiently."*
- DOE first launched its competitive sourcing program in March 2002. As a result of the A-76 competition for financial services, the Oak Ridge Financial Service Center, funded by SCPD, provides payment services for the entire DOE/NNSA, nation-wide. In FY 2004, SC, as well as other Departmental organizations, participated in the A-76 Fair Act Review. DOE's Competitive Sourcing Executive Steering Group (CSESG) recently approved the functions and positions that will be included in the next round of DOE competitive sourcing studies. The CSESG approved a study involving 684 positions that perform Environmental Engineering Services functions such as environmental technical review, evaluation, and associated project and program work, including 121 positions funded by SC. Impact on SC will not be known until the study has been completed.

Program Direction

Funding Profile by Category

	(dollars in thousands/whole FTEs)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Headquarters					
Salaries and Benefits	40,801	42,905	46,378	+3,473	+8.1%
Travel	1,731	1,681	1,923	+242	+14.4%
Support Services	14,430	10,893	11,022	+129	+1.2%
Other Related Expenses	9,296	9,418	10,809	+1,391	+14.8%
Total, Headquarters	66,258	64,897	70,132	+5,235	+8.1%
Full Time Equivalents	315	347	349	+2	+0.6%

Mission

The Program Direction subprogram funds all of the SC Federal staff in headquarters responsible for SC-wide issues and operational policy, scientific program development, and management functions supporting the broad spectrum of scientific disciplines and program offices. These disciplines include the Advanced Scientific Computing Research, Basic Energy Sciences, Biological and Environmental Research, Fusion Energy Sciences, High Energy Physics, Nuclear Physics, and Workforce Development for Teachers and Scientists programs. Additionally, this subprogram supports management of workforce program direction and infrastructure through policy, technical, and administrative support staff responsible for: budget and planning; general administration; information technology; infrastructure management; construction management; S&S; and ES&H within the framework set by the Department.

Funding for OSTI is also provided within this subprogram activity. OSTI's mission is to advance science and sustain technological creativity by making R&D findings available and useful to DOE researchers and the American people. OSTI is responsible for the development and operation of DOE's leading e-government systems such as the Information Bridge, Energy Citations Database, and the E-Print Network. On an annual basis, there are over 15 million downloads or "views" of R&D findings on these and other OSTI systems. OSTI also developed and hosts the interagency e-government system Science.gov, which uses breakthrough technology for simultaneously searching across 47 million pages in 30 federal databases involving 12 different federal agencies. Although the majority of DOE's R&D output is open to the scientific community, a sizable share is classified or sensitive. Here, OSTI's responsibilities are to ensure protection and limited, appropriate access in order to promote national security.

By supporting the Federal workforce (to include travel, training, contractual services, Working Capital Fund (WCF), and other related expenses), SC is able to deliver the remarkable discoveries and scientific tools that transform our understanding of energy and matter and to advance the national, economic, and energy security of the United States.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Salaries and Benefits..	**40,801**	**42,905**	**46,378**

- Supports 349 FTEs at headquarters pending completion of OneSC Phase 2 activities currently underway which include human capital and organizational needs analyses and reengineering of SC business and management operations and processes. Changes in staffing levels and realignment of skills resulting from completion of Phase 2 activities and full implementation of the OneSC Project will be managed through attrition, retraining, and reassignments. No downgrades, involuntary geographical transfers, separations, or reductions-in-force are planned or expected. In addition, headquarters staffing levels will address the highest priority concerns identified by recent Committee of Visitors (COVs) reports.
- Includes funding for enhanced recruitment, relocation and retention bonuses as authorized by the recently enacted Federal Workforce Flexibility Act of 2004. These bonuses will be strategically used to corporately recruit and maintain a highly technical and qualified workforce. In addition, the FY 2006 request assumes the increased pay cap for Senior Executive Service (SES) basic pay, which was raised from $146,600 to $158,100.
- The FY 2006 request assumes a 2.6% pay raise in 2006.

Travel	**1,731**	**1,681**	**1,923**

- Travel includes all costs of transportation of persons, subsistence of travelers and incidental travel expenses in accordance with Federal travel regulations. The FY 2006 increased travel request is related to the Congressionally-mandated competition of the Berkeley, Argonne, and Ames laboratory contracts; and competition of the Fermi National Accelerator Laboratory.

Support Services...	**14,430**	**10,893**	**11,022**

- Provides funding for general administrative services and technical expertise provided as part of day-to-day operations, including mailroom operations, travel management, cyber security support, and administration of the Small Business Innovation Research program. Also provides for information technology (IT) support to include the following: (1) maintenance and operation of headquarters information management systems and infrastructure; (2) enhancement of phase 1 of the e-Government Corporate R&D Portfolio Management, Tracking and Reporting Environment (ePME) project by developing the capability to receive and review all national laboratory work proposals versus only R&D proposals; and (3) accessibility of DOE's multi-billion dollar R&D program through the e-Government information systems administered by OSTI. Training and education of Federal staff is also included.
- The funding increase in FY 2006 will support the Congressionally-mandated competition of the Berkeley, Argonne, and Ames laboratory contracts; and competition of the Fermi National Accelerator Laboratory. Short-term administrative and technical expertise support will be required in the areas of ES&H, S&S, contract management, property management, pension planning, etc., to ensure that the awarded contracts provide the Department with enhanced contractor performance and productivity.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- Funding also supports SC strategic planning and analysis activities including: societal and economic impact studies of basic research outcomes; development of methods to assess the SC portfolio, including benchmarking and planning studies; and development of performance metrics and models of scientific human resource flows.
- Capital Equipment funding is included for SC headquarters upgrade of 2 network storage filer heads ($147,000) and OSTI T3 Storage Arrays ($125,000).

	FY 2004	FY 2005	FY 2006
Other Related Expenses	**9,296**	**9,418**	**10,809**

- Provides support through the WCF to headquarters for office space, utilities, building/equipment maintenance, mail services, LAN connections, supplies, and other services and equipment. Also provides for communications, utilities building/equipment maintenance, supplies, equipment, and other services at OSTI. The increase in FY 2006 is primarily related to additional WCF requirements associated with operation and maintenance of the Standard Accounting and Reporting System (STARS); IT project management training; E-Government initiative fees for E-Travel, Business Gateway, Integrated Acquisition Environment, and Grants.gov; and a non-pay inflation factor increase of 2.0%.

	FY 2004	FY 2005	FY 2006
Total, Program Direction	**66,258**	**64,897**	**70,132**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Salaries and Benefits	
FY 2006 increase related to a 2.6% pay-raise assumption, enhanced recruitment, relocation, and retention bonuses, as authorized by the Federal Workforce Flexibility Act of 2004; and increased pay cap for SES base pay.	**+3,473**
Travel	
FY 2006 increase due to additional travel requirements related to the Congressionally mandated competition of the Berkeley, Argonne, and Ames laboratory contracts, and competition of the Fermi National Accelerator Laboratory.	**+242**
Support Services	
FY 2006 increase primarily due to the short-term requirement for administrative and technical expertise support related to competition of the Berkeley, Argonne, Ames, and Fermi laboratory contracts. This increase is offset by a decrease to S&S administrative and technical support at headquarters, which will be phased out in FY 2005 and performed by federal staff.	**+129**

	FY 2006 vs. FY 2005 ($000)

Other Related Expenses

- FY 2006 increase primarily related to STARS and IT project management training; e-Government initiative fees; and a non-pay inflation factor increase of 2.0%. This increase is partially offset by the completion, in FY 2005, of a major computer infrastructure upgrade at OSTI. .... **+1,391**

Total Funding Change, Program Direction .... **+5,235**

Support Services by Category

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Technical Support					
Feasibility of Design Considerations	100	130	130	0	0.0%
Development of Specifications	256	350	370	+20	+5.7%
System Definition	50	160	180	+20	+12.5%
System Review and Reliability Analyses	450	475	485	+10	+2.1%
Trade-off Analyses	50	55	55	0	0.0%
Test and Evaluation	619	156	169	+13	+8.3%
Total, Technical Support	1,525	1,326	1,389	+63	+4.8%
Management Support					
Automated Data Processing	10,026	6,698	6,775	+77	+1.1%
Training and Education	285	287	290	+3	+1.0%
Reports and Analyses Management and General Administrative Services	2,594	2,582	2,568	-14	-0.5%
Total, Management Support	12,905	9,567	9,633	+66	+0.7%
Total, Support Services	14,430	10,893	11,022	+129	+1.2%

Other Related Expenses by Category

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Other Related Expenses					
Communications, Utilities, Miscellaneous	340	350	368	+18	+5.1%
Printing and Reproduction	1	2	2	0	0.0%
Other Services	4,757	4,124	4,099	-25	-0.6%
Operation & Maintenance of Equipment	60	100	110	+10	+10.0%
Supplies and Materials	50	55	60	+5	+9.1%
Equipment	80	420	125	-295	-70.2%
Working Capital Fund	4,008	4,367	6,045	+1,678	+38.4%
Total, Other Related Expenses	9,296	9,418	10,809	+1,391	+14.8%

Field Operations

Funding Profile by Category

(dollars in thousands/whole FTEs)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Chicago Office (CH)					
Salaries and Benefits	19,426	20,420	20,479	+59	+0.3%
Travel	306	200	200	0	0.0%
Support Services	1,434	1,191	2,202	+1,011	+84.9%
Other Related Expenses	2,825	2,168	2,525	+357	+16.5%
Total, CH	23,991	23,979	25,406	+1,427	+6.0%
Full Time Equivalents, CH	181	195	191	-4	-2.1%
Ames Site Office (AMSO)					
Salaries and Benefits	307	398	412	+14	+3.5%
Travel	12	12	15	+3	+25.0%
Support Services	12	22	23	+1	+4.5%
Other Related Expenses	24	11	3	-8	-72.7%
Total, AMSO	355	443	453	+10	+2.3%
Full Time Equivalents, AMSO	3	3	3	0	0.0%
Argonne Site Office (ASO)					
Salaries and Benefits	2,515	3,035	3,127	+92	+3.0%
Travel	23	35	25	-10	-28.6%
Support Services	152	200	198	-2	-1.0%
Other Related Expenses	300	326	327	+1	+0.3%
Total, ASO	2,990	3,596	3,677	+81	+2.3%
Full Time Equivalents, ASO	23	25	25	0	0.0%
Berkeley Site Office (BSO)					
Salaries and Benefits	2,278	2,774	2,764	-10	-0.4%
Travel	16	96	96	0	0.0%
Support Services	70	180	182	+2	+1.1%
Other Related Expenses	69	252	263	+11	+4.4%
Total, BSO	2,433	3,302	3,305	+3	+0.1%
Full Time Equivalents, BSO	16	23	23	0	0.0%

(dollars in thousands/whole FTEs)	FY 2004	FY 2005	FY 2006	$ Change	% Change
Brookhaven Site Office (BHSO)					
Salaries and Benefits	2,642	2,969	3,062	+93	+3.1%
Travel	57	50	50	0	0.0%
Support Services	140	238	238	0	0.0%
Other Related Expenses	121	199	187	-12	-6.0%
Total, BHSO	2,960	3,456	3,537	+81	+2.3%
Full Time Equivalents, BHSO	20	24	24	0	0.0%
Fermi Site Office (FSO)					
Salaries and Benefits	1,926	1,920	1,977	+57	+3.0%
Travel	29	48	40	-8	-16.7%
Support Services	110	105	125	+20	+19.0%
Other Related Expenses	110	116	93	-23	-19.8%
Total, FSO	2,175	2,189	2,235	+46	+2.1%
Full Time Equivalents, FSO	15	15	15	0	0.0%
Princeton Site Office (PSO)					
Salaries and Benefits	1,418	1,499	1,544	+45	+3.0%
Travel	14	15	15	0	0.0%
Support Services	0	10	10	0	0.0%
Other Related Expenses	73	59	49	-10	-16.9%
Total, PSO	1,505	1,583	1,618	+35	+2.2%
Full Time Equivalents, PSO	12	12	12	0	0.0%
Stanford Site Office (SSO)					
Salaries and Benefits	960	1,400	1,439	+39	+2.8%
Travel	17	48	52	+4	+8.3%
Support Services	31	106	110	+4	+3.8%
Other Related Expenses	37	101	108	+7	+6.9%
Total, SSO	1,045	1,655	1,709	+54	+3.3%
Full Time Equivalents, SSO	10	12	12	0	0.0%
Oak Ridge Office (OR)					
Salaries and Benefits	27,223	27,536	28,720	+1,184	+4.3%
Travel	598	418	430	+12	+2.9%
Support Services	5,712	6,212	6,413	+201	+3.2%
Other Related Expenses	7,757	7,756	8,195	+439	+5.7%
Total, OR	41,290	41,922	43,758	+1,836	+4.4%
Full Time Equivalents, OR	284	301	298	-3	-1.0%

	(dollars in thousands/whole FTEs)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Pacific Northwest Site Office (PNSO)					
Salaries and Benefits	3,624	4,115	4,345	+230	+5.6%
Travel	49	91	93	+2	+2.2%
Support Services	12	134	136	+2	+1.5%
Other Related Expenses	560	937	864	-73	-7.8%
Total, PNSO	4,245	5,277	5,438	+161	+3.1%
Full Time Equivalents, PNSO	32	36	36	0	0.0%
Thomas Jefferson Site Office (TJSO)					
Salaries and Benefits	918	1,275	1,314	+39	+3.1%
Travel	47	66	67	+1	+1.5%
Support Services	0	19	19	0	0.0%
Other Related Expenses	65	47	57	+10	+21.3%
Total, TJSO	1,030	1,407	1,457	+50	+3.6%
Full Time Equivalents, TJSO	8	11	11	0	0.0%
Total Field Operations					
Salaries and Benefits	63,237	67,341	69,183	+1,842	+2.7%
Travel	1,168	1,079	1,083	+4	+0.4%
Support Services	7,673	8,417	9,656	+1,239	+14.7%
Other Related Expenses	11,941	11,972	12,671	+699	+5.8%
Total, Field Operations	84,019	88,809	92,593	+3,784	+4.3%
Full Time Equivalents, Field Operations	604	657	650	-7	-1.1%

Mission

The Field Operations subprogram is the centralized funding source for the SC Field Federal workforce. Responsibilities include the Integrated Support Center (ISC) (comprised by the CH and OR Offices) management and administrative functions and the site offices' oversight of Management and Operating contract performance supporting SC laboratories and facilities. These SC laboratories and facilities include Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge, and Pacific Northwest national laboratories, and Ames laboratory, Fermi National Accelerator Laboratory, Princeton Plasma Physics Laboratory, Stanford Linear Accelerator Center, and Thomas Jefferson National Accelerator Facility.

This subprogram supports the field Federal workforce responsible for SC and other DOE programmatic missions performed in support of science and technology, energy research, and environmental management. Workforce operations include financial stewardship, human resources (HR), grants and contracts, labor relations, security, legal counsel, public and congressional liaison, intellectual property and patent management, environmental compliance, safety and health management, infrastructure operations maintenance, and information systems development and support.

In addition, this subprogram provides funding for the fixed requirements associated with rent, utilities, and telecommunications. Other requirements such as IT maintenance, administrative support, mail services, document classification, personnel security clearances, emergency management, printing and reproduction, travel, certification training, vehicle acquisition and maintenance, equipment, classified/unclassified data handling, records management, health care services, and facility and ground maintenance are also included. Services provided through the Department's WCF include online training in the Corporate Human Resource Information System and payroll processing. These infrastructure requirements are relatively fixed. This subprogram also supports the Inspector General operations located at each site by providing office space and materials. Other operational requirements funded include occasional contractor support to perform ecological surveys, cost validations, and environmental assessments; ensure compliance with Defense Nuclear Facilities Safety Board safety initiatives; abide by site preservation laws and regulations; and perform procurement contract closeout activities.

Detailed Justification

(dollars in thousands)

	FY 2004	FY 2005	FY 2006
Salaries and Benefits..	**63,237**	**67,341**	**69,183**

- Supports 650 FTEs in the SC field complex pending completion of OneSC Phase 2 activities currently underway which include human capital and organizational needs analyses and reengineering of SC business and management operations and processes. The reduction in FTEs will be accomplished through attrition (-7 FTEs) and accommodated by expected efficiencies resulting from implementation and reengineering during Phase 2 of OneSC. The FY 2006 salary request assumes a 2.6% pay raise in 2006.

	FY 2004	FY 2005	FY 2006
Travel	**1,168**	**1,079**	**1,083**

- Enables field staff to participate on task teams, work various issues, conduct compliance reviews, and perform contractor oversight to ensure implementation of DOE orders and regulatory requirements at the facilities under their purview. Also provides for attendance at conferences and training classes, permanent change of station relocation, etc. The FY 2006 request incorporates the non-pay inflation factor of 2.0%.

	FY 2004	FY 2005	FY 2006
Support Services..	**7,673**	**8,417**	**9,656**

- The field uses a variety of administrative and technical assistance services that are critical to their success in meeting local customer needs. The services provided support routine computer maintenance, specific IT improvements, operating systems upgrades, cyber security, network monitoring, firewalls, and disaster recovery tools. Other areas include staffing 24-hour emergency and communications centers, processing/distributing mail, travel management centers, contract close-out activities, copy centers, directives coordination, filing and retrieving records, etc. Training and education of Federal staff is also included.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

- Automated Data Processing (ADP) related increases support current operating levels at CH (+$407,000) in the areas of hardware/software maintenance, web server, and cyber security across the full range of services provided to key areas; e.g., contract/grant awards and closeouts, processing of accounting transactions, human resource support to the site managers and headquarters, and legal/intellectual property assistance. Also supports 3% ADP contract escalation rate at OR (+$90,000). The reports and Analyses-related increase directly supports the current operating level for the closeout contract at CH (+$602,000). Increase also represents 3% escalation rate in OR mail/file and directives management support contracts (+$75,000).

Other Related Expenses	**11,941**	**11,972**	**12,671**

- Funds day-to-day requirements associated with operating a viable office, including fixed costs associated with occupying office space, utilities, telecommunications, and other costs of doing business, e.g., postage, printing and reproduction, copier leases, site-wide health care units, records storage assessments, office equipment/furniture, supplies, and building maintenance.
- Increase related to Rent to Others at CH (+$216,000) represents current fixed costs. Other Services (+$156,000) and Operation and Maintenance of Equipment (+$149,000) related increases support current operating levels at OR.

Total, Field Operations	**84,019**	**88,809**	**92,593**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Salaries and Benefits	
■ Supports 650 FTEs and assumes a 2.6% pay raise in 2006. Reduced levels of FTEs are accomplished through attrition and reflect expected efficiencies resulting from implementation of OneSC...	**+1,842**
Travel	
■ Increase supports Federal workforce and incorporates the non-pay inflation factor of 2.0%.	**+4**
Support Services	
■ Increase supports current operating level for ADP contracts; Reports/Analysis Management and General Administrative Services activities; and slight increase to support services across multiple offices.	**+1,239**
Other Related Expenses	
■ Increase supports current operating level for Rent to Others, Other Services and Operation/Maintenance of Equipment activities at Oak Ridge and Chicago Field Offices...	+580

	FY 2006 vs. FY 2005 ($000)
■ Increase of other fixed operating costs (i.e., rent to GSA and Communications, Utilities, Miscellaneous) across multiple offices.	+67
■ Other related expenses (i.e., printing/reproduction, other services, operation/maintenance, supplies/materials, and equipment) increase across multiple offices.	+52
Total, Other Related Expenses	**+699**
Total Funding Change, Field Operations	**+3,784**

Support Services by Category

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Technical Support					
Development of Specifications	0	18	18	0	0.0%
System Review and Reliability Analyses	0	18	7	-11	-61.1%
Total, Technical Support	0	36	25	-11	-30.6%
Management Support					
Directives Management Studies	300	309	318	+9	+2.9%
Automated Data Processing	3,985	4,415	4,936	+521	+11.8%
Preparation of Program Plans	61	330	340	+10	+3.0%
Training and Education	704	968	1,001	+33	+3.4%
Reports and Analyses Management and General Administrative Services	2,623	2,359	3,036	+677	+28.7%
Total, Management Support	7,673	8,381	9,631	+1,250	+14.9%
Total, Support Services	7,673	8,417	9,656	+1,239	+14.7%

Other Related Expenses by Category

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Other Related Expenses					
Rent to GSA.	859	888	915	+27	+3.0%
Rent to Others	386	1,433	1,653	+220	+15.4%
Communications, Utilities, Miscellaneous	2,866	2,782	2,822	+40	+1.4%
Printing and Reproduction	64	107	109	+2	+1.9%
Other Services	3,652	2,972	3,180	+208	+7.0%
Purchases from Government Accounts	1	0	0	0	0.0%
Operation and Maintenance of Equipment	1,944	1,691	1,843	+152	+9.0%
Supplies and Materials	1,530	1,510	1,543	+33	+2.2%
Equipment	139	289	306	+17	+5.9%
Working Capital Fund	500	300	300	0	0.0%
Total, Other Related Expenses	11,941	11,972	12,671	+699	+5.8%

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Capital Equipment	162	607	272	-335	-55.2%

Workforce Development for Teachers and Scientists

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Workforce Development for Teachers and Scientists					
Undergraduate Internships	3,607	3,483	-56[a]	3,427	3,123
Graduate/Faculty Fellowships.............	1,930	3,060	-5[a]	3,055	3,080
Pre-College Activities	895	1,117	0	1,117	989
Total, Workforce Development for Teachers and Scientists	6,432[b]	7,660	-61	7,599	7,192

Public Law Authorizations:
Public Law 95-91, "Department of Energy Organization Act"
Public Law 103-62, "Government Performance and Results Act of 1993"
The Omnibus Energy Legislation: Sec. 995. Educational Programs in Science and Mathematics amends the Public Law 101-510, "DOE Science Education Enhancement Act"

Mission

The mission of the Workforce Development for Teachers and Scientists (WDTS) program is to provide a continuum of educational opportunities to the Nation's students and teachers of science, technology, engineering, and mathematics (STEM).

WDTS performs the following functions in support of its overall mission: (1) provides mentor-intensive research experiences at the national laboratories for undergraduate students to inspire commitments to the technical disciplines and pursue careers in science, technology, engineering and mathematics thereby helping our national laboratories and the Nation meet the demand for a well-trained scientific/technical workforce; (2) builds an interactive link between the national laboratories and the science-education community by providing mentor research experiences at the national laboratories to teachers and college faculty to enhance their content knowledge and research capabilities; and (3) encourages middle and high school students across the nation to share, demonstrate, and excel in math and the sciences, and introduces these students to the national laboratories and the opportunities available to them when they go to college.

Benefits

Through this unified program, WDTS can attract, train, and retain the talent needed to supply our national laboratories with the workforce it will need to execute the compelling science that the Office of Science (SC) will conduct in the coming years.

WDTS supports three science, technology and workforce development subprograms: 1) Undergraduate Internships, for a broad base of undergraduate students planning to enter STEM careers, including

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[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes a reduction of $38,000 rescinded in accordance with P.L. 108-137, the Consolidated Appropriations Act, 2004.

teaching; 2) Graduate/Faculty Fellowships for STEM students, teachers, and faculty; and 3) Pre-College Activities for middle and high school students, the principle effort being the Middle and High School National Science Bowls. Each subprogram targets a different group of students and teachers to attract a broad range of participants to the programs and to expand the pipeline of students who will enter the STEM workforce. In this fashion, the subprograms use our national laboratories to meet the Department's needs, as well as a national need, for a well-trained scientific and technical workforce. The program also has a focus on professional development for teachers and faculty who often serve their students as the primary models and inspiration for entering the scientific and technical workforce.

Significant Program Shifts

On July 8, 2004, the Department of Energy (DOE) announced the Scientists Teaching and Reaching Students (STARS) education initiative to promote science literacy and help develop the next generation of scientists and engineers. In support of this effort, there is additional funding to both the Laboratory Science Teacher Professional Development (LSTPD) activity and to the Middle School Science Bowl in FY 2006. The components of the STARS initiative that involve educational outreach by national laboratory scientists and engineers to middle school students will be executed by the national laboratories through their respective workforce development/education offices.

The LSTPD activity is a 3 year commitment experience for K-14 teachers and faculty and was designed to add a cohort of 60 teachers each year. FY 2006 represents the third year of this program. The first cohort of 62 teachers began in FY 2004, the second cohort of approximately 28 teachers begins in FY 2005, and the third cohort of 15 teachers will begin in FY 2006. The LSTPD will run at five or more DOE national laboratories with about 105 participating STEM teachers, in response to the national need for science teachers who have strong content knowledge in the classes they teach. DOE national laboratories provide mentor-intensive, research-focused professional development where the teacher is immersed in the culture and world of science and technology. The multidisciplinary, team-centered, scientific culture of the national laboratories is an ideal setting for teachers to fully comprehend the science and technology principles they are asked to teach. More importantly, the extensive mentoring power of our laboratory scientists and their commitment to knowledge transfer are ideal means to establish a link between teachers, their classroom, and the scientific community. Armed with this knowledge and experience, teachers enter the classroom as genuine and effective representatives of the exciting world of science and technology. Teacher classroom performance and student commitment to STEM career paths will help measure the long-term impact of this program.

The Faculty Sabbatical activity, which is being initiated in FY 2005 for 12 faculty members from Minority Serving Institutions (MSI), will have five positions available in FY 2006. The Faculty Sabbatical is aimed at providing sabbatical opportunities to faculty members from MSIs to facilitate the entry of their faculty into the research funding mainstream. This activity is an extension of the successful Faculty and Student Teams (FaST) program where teams consisting of a faculty member and two or three undergraduate students, from colleges and universities with limited prior research capabilities, work with mentor scientists at a national laboratory to work on a research project that is formally documented in a paper or presentation.

In the FY 2006 request, the Pre-Service Teachers (PST) activity will be run at one national laboratory, as opposed to eight national laboratories in FY 2005, and students will be recruited from participating National Science Foundation (NSF) programs.

Supporting Information

As documented by a July 2001 DOE Inspector General report, the Department faces a critical and immediate shortage of scientific and technical staff sufficient to meet its mission requirements. In their report on "Recruitment and Retention of Scientific and Technical Personnel", (DOE/IG-0512, July 2001, http://www.ig.doe.gov/pdf/ig-0512.pdf), GAO reported that "the Department was unable to recruit and retain critical scientific and technical staff in a manner sufficient to meet identified mission requirements. Based on their analysis of attrition and hiring since 1999, GAO determined that as of January 2001, the Department faced an immediate need for as many as 577 scientific and technical specialists. Further, if this trend continues, the Department could face a shortage of nearly 40% in these classifications within five years." WDTS is addressing this shortfall by managing its current programs, and initiating target programs, that align with the mission of SC and the national laboratories.

The WDTS program provides a grade school through post-graduate school set of opportunities that are unified under the common belief that DOE national laboratories can provide unique training and professional development research experiences that enhance the technical skills and content knowledge in science and mathematics of teachers and students, strengthen their investigative expertise, inspire commitments to science and engineering careers, and build a link between the resources of the national laboratories and the science education community. These opportunities are complimentary to the efforts of other federal agencies, such as the NSF and the Department of Education, and provide support that might otherwise be unavailable to these agencies' programs and students they serve.

Undergraduate Internships

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Undergraduate Internships					
Science Undergraduate Laboratory Internship	2,492	2,587	2,663	+76	+2.9%
Community College Institute of Science and Technology	605	423	430	+7	+1.7%
Pre-Service Teachers	510	417	30	-387	-92.8%
Total, Undergraduate Internships	3,607	3,427	3,123	-304	-8.9%

Description

The mission of the Undergraduate Internships subprogram is to continue the Department's long-standing role of providing mentor-intensive research experiences at the national laboratories for undergraduate students to enhance their content knowledge in science and mathematics and their investigative expertise; and to inspire commitments to careers in science, engineering, and K-12 STEM teaching. Through providing a wide variety of college undergraduates the opportunity to work directly with many of the world's best scientists and use the most advanced scientific facilities available, this program will expand the Nation's supply of highly skilled scientists and engineers, especially in the physical sciences where the greatest demand lies because of a steady decline in U.S. citizens entering these fields.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts from the subprograms which support the GPRA Units in carrying out their mission. Undergraduate Internships performs three functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

The Undergraduate Internships subprogram provides a wide diversity of opportunities for undergraduate students to see and experience what a career in a national laboratory has to offer. It allows the national laboratories to have a broader and more skilled pool from which to draw employees. It also provides the laboratory mentors with a more enriching environment in which to conduct their research.

Supporting Information

The Undergraduate Internships subprogram contains three activities:

The Science Undergraduate Laboratory Internship (SULI) strengthens the students' academic training and introduces them to the unique intellectual and research facility resources present at the national laboratories. Research internships are available during the spring, summer, and fall terms.

The Community College Institute (CCI) of Science and Technology provides a 10-week summer workforce development program through research experiences at several DOE national laboratories for highly motivated community college students. The CCI is targeted at underserved community college students who have not had an opportunity to work in an advanced science-research environment. It incorporates both an individually mentored research component and a set of enrichment activities that include lectures, classroom activities, career guidance/planning, and field trips.

Pre-Service Teachers (PST) is for undergraduate students who plan on pursuing a teaching career in science, technology, engineering, or mathematics. Students work with scientists or engineers on projects related to the laboratories' research programs. They also have the mentorship of a master teacher who is currently working in K-12 education as a teacher and is familiar with the research environment of a specific national laboratory.

FY 2004 Accomplishments

- WDTS has fully implemented an innovative, interactive Internet system for all SC national workforce development programs, to receive and process hundreds of student and teacher/faculty applications for summer, fall, and spring semester research appointments at participating DOE laboratories. The on-line application system is linked with an SC laboratory central processing center, called Education Link, and allows the students and researchers at the laboratories to select and match in research areas of common interest.
- Through special recruitment efforts, the Undergraduate Internships have attracted a diverse group of students using the electronic application. Over 9% of those submitting applications were from under-represented groups. Approximately 48% of the applicants were females, and more than 6% were from low-income families. There were 462 internship appointments made in FY 2001, 277 in FY 2002, 569 in FY 2003, and 670 in FY 2004. All appointments are made through the on-line application process.
- In order to document and evaluate the quality of the research experience and the collaboration of the intern with their mentor researcher, the program publishes the "Journal of Undergraduate Research" containing full-length peer-reviewed research papers and abstracts of students' research in the activity. All scientific research abstracts are graded to measure the quality of the students' ability to prepare scientific manuscripts. A fourth edition was published in 2004, with 22 full-length papers and 422 abstracts. In 2004, more than 96% of all students in undergraduate research internships submitted abstracts and research papers. The students who published full-length papers presented their work at a poster session at the American Association for the Advancement of Science (AAAS) national meeting. Students have received awards at these events for their research and the communication of their accomplishments.
- The "Undergraduate Internships Program Guidebook" was revised. It is an invaluable tool for both students and laboratory research mentors as it describes the responsibilities, requirements, and outcomes that are associated with a successful internship. The guidebook contains formats and instructions for the written requirements, including scientific abstract, research paper, oral presentation, and poster; and instructions for an education module for the PST activity.
- CCI is open to students from all community colleges. In the summer of 2004, 88 community college students attended a 10-week mentor-intensive scientific research experience at several DOE national laboratories. About 22% of the participating students came from underrepresented groups in STEM disciplines; many were "non-traditional" students. Grades of abstracts for these students were statistically equal to those from the four-year program. Twelve community college students also participated with faculty members as part of a FaST.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Science Undergraduate Laboratory Internship (SULI)..	**2,492**	**2,587**	**2,663**

SULI supports a diverse group of students at our national laboratories in individually mentored research experiences. Through these unique and highly focused experiences these students will become a repository of talent to help the DOE meet its science mission goals. Students in the program: 1) apply on a competitive basis and are matched with mentors working in the students' fields of interest; 2) spend an intensive 10-16 weeks working under the individual mentorship of resident scientists; 3) produce an abstract and formal research paper; and 4) attend seminars that broaden their view of career options and help them understand how to become members of the scientific community. Activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys, and outside evaluation. An undergraduate student journal is produced annually that publishes selected full research papers and all abstracts of students in the activity. Full research papers published in the journal are presented by the student authors at the annual national conference of the AAAS and the abstracts of their presentations are posted on the AAAS web site. The NSF collaborates with DOE to offer students in its undergraduate student programs access to individually mentored research internships that they would otherwise not have. This activity will ensure a steady flow of students with growing interest in science careers into the Nation's pipeline of workers in both academia and industry. A system is being refined to track students in their academic career paths. In FY 2004, with DOE, NSF and other leveraged support, 43 students participated in the spring semester program, 405 students participated in the summer, and about 30 students are expected in the fall semester program. The DOE contribution will support an estimated 345 students in FY 2005 and 358 students in FY 2006.

Community College Institute of Science and Technology (CCI)..	**605**	**423**	**430**

This activity is designed to address shortages, particularly at the technician and paraprofessional levels, and will help develop the workforce needed to continue building the Nation's capacity in critical areas for the next century. Since community colleges account for more than half of the entire Nation's undergraduate enrollment, this is a clear avenue to find and develop talented scientists and engineers. The CCI particularly targets students from under represented populations in the science and technology fields to increase the diversity of the workforce. The CCI provides a 10-week mentored research internship at a DOE national laboratory for highly motivated community college students. Students in the program: 1) apply on a competitive basis and are matched with mentors working in the students' field of interest; 2) spend an intensive ten weeks working under the individual mentorship of resident scientists; 3) produce an abstract and formal research paper; and 4) attend professional enrichment activities, workshops, and seminars that broaden their view of career options, help them understand how to become members of the scientific community, and enhance their communication and other professional skills. Activity goals and outcomes are measured based on students' research papers, students' abstracts, surveys, and outside evaluation. An ongoing undergraduate student journal was created to publish selected full research papers and all abstracts of students in this activity. CCI was originally a collaborative effort with DOE, its national laboratories, the American Association of Community Colleges, and specified member institutions. Through a Memorandum of Understanding with the NSF in FY 2001, undergraduate students in NSF programs (e.g., the Louis Stokes Alliance for

	FY 2004	FY 2005	FY 2006

(dollars in thousands)

Minority Participation and Advanced Technology Education program) are also participating in this activity. This allows NSF's undergraduate programs to include a community college internship in the opportunities they provide to students. The CCI program is now available to students from all community colleges.

In FY 2004, 88 students directly participated in this internship, with approximately 70 students participating in FY 2005 and 71 students participating in FY 2006.

Pre-Service Teachers (PST)	**510**	**417**	**30**

The PST activity is for students who are preparing for a teaching career in a STEM discipline. This effort is aimed at addressing the national need to improve content knowledge of STEM teachers prior to entering the teaching workforce. The NSF entered into a collaboration with SC on this activity in FY 2001. This allows NSF's undergraduate pre-service programs to include a PST internship in the opportunities they provide to students. Students in this program: 1) apply on a competitive basis and are matched with mentors working in the student's field of interest; 2) spend an intensive ten weeks working under the mentorship of master teachers and laboratory scientists to help maximize the building of content, knowledge, and skills through the research experience; 3) produce an abstract and an educational module related to their research and also may produce a research paper or poster or oral presentation; and 4) attend professional enrichment activities, workshops, and seminars that help students apply what they learn to their academic program and the classroom, and also to help them understand how to become members of the scientific community, and enhance their communication and other professional skills. Activity goals and outcomes are measured based on students' abstracts, education modules, surveys, and outside evaluation. In FY 2004, 63 students participated in this program. Approximately 69 students in FY 2005 and about 10 students in FY 2006 are expected to participate in the PST activity. The PST will be hosted at only one national laboratory in FY 2006 as compared to 12 in FY 2005. Within the FY 2006 request for WDTS, priority was given to sustaining the Faculty Sabbatical Fellowship, initiated in FY 2005, and to adding a very small number of teachers to the LSTPD. The PST internship was significantly reduced in FY 2006 to accommodate the overall WDTS priorities.

Total, Undergraduate Internships	**3,607**	**3,427**	**3,123**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Undergraduate Internships	
Science Undergraduate Laboratory Internship	
The number of students participating in SULI increases by 13 students from 345 students in FY 2005 to 358 students in FY 2006.	+76

	FY 2006 vs. FY 2005 ($000)
Community College Institute of Science and Technology	
The number of students participating in CCI increases by 1 student, from 70 students in FY 2005 to 71 students in FY 2006.	+7
Pre-Service Teachers	
The number of students participating in the PST decreases by 59 students, from 69 students in FY 2005 to ten students in FY 2006.	-387
Total Funding Change, Undergraduate Internships	**-304**

Graduate/Faculty Fellowships

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Graduate/Faculty Fellowships					
Laboratory Science Teacher Professional Development	1,035	1,500	1,840	+340	+22.7%
Faculty and Student Teams	215	265	250	-15	-5.7%
Albert Einstein Distinguished Educator Fellowship	600	700	700	0	0.0%
Energy Related Laboratory Equipment	80	90	90	0	0.0%
Faculty Sabbatical Fellowship	0	500	200	-300	-60.0%
Total, Graduate/Faculty Fellowships	1,930	3,055	3,080	+25	+0.8%

Description

The mission of the Graduate/Faculty Fellowships subprogram is to build a link between the resources of the national laboratories and the science education community by providing mentor-intensive research experiences at the national laboratories to teachers and faculty to enhance their content knowledge in science and mathematics and their investigative expertise, and to enhance the research capabilities at academic institutions.

The SC Program Goals will be accomplished not only through the efforts of the direct (GRPA Unit) programs but with additional efforts from the subprograms which support the GPRA Units in carrying out their mission. Graduate/Faculty Fellowships performs five functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

These Graduate/Faculty Fellowship activities bring in fresh ideas and a greater diversity of faculty and colleges interacting with the national laboratories.

Supporting Information

The Graduate/Faculty Fellowships subprogram contains five activities:

The Laboratory Science Teacher Professional Development (LSTPD) program addresses the Administration’s goal of a “qualified teacher in every classroom,” and supports the DOE’s education initiative—Scientists Teaching and Reaching Students (STARS). The program provides K-14 classroom teachers long-term, mentor-intensive professional development through scientific research opportunities at the national laboratories. The goal of the program is to improve teachers' content knowledge, student achievement in STEM, and numbers of students pursuing STEM careers. The desired outcome is that students will show increased involvement in STEM courses, extracurricular activities and pursuit of higher level STEM courses and ultimately show rising average scores on standardized tests. Teachers completing the initial laboratory summer experience will be provided monetary support to: help them extend what they have learned to their classes; connect students via classroom activities to ongoing national laboratory research; continue communication and collaboration with other participant teachers and laboratory scientists; take subject enhancement trips to the laboratory; and, present their experiences at professional conferences and in publications.

The Faculty and Student Teams (FaST) program provides research opportunities at national laboratories to faculty and undergraduate students from colleges and universities, including community colleges, with limited prior research capabilities as well as institutions serving populations underrepresented in the fields of science, technology, engineering, and mathematics, particularly women and minorities. These opportunities are also extended to faculty from NSF funded institutions.

The Faculty Sabbatical Fellowship program is an extension of the successful FaST program. It provides a research fellowship for a faculty member from a Minority Serving Institution (MSI) to collaborate with resident scientists at a national laboratory for up to one year on research projects specific to the visiting professors' areas of investigation and the courses they teach. It is the extended stay at the laboratory, along with the concentrated support, that will enhance them as professors and help them better prepare and apply for grants from federal science agencies and other granting institutions.

The Albert Einstein Distinguished Educator Fellowship activity supports outstanding K-12 science and mathematics teachers, who provide insight, extensive knowledge, and practical experience to the legislative and executive branches. This activity is in compliance with the Albert Einstein Distinguished Educator Act of 1994, which gives the DOE responsibility for administering the activity of distinguished educator fellowships for elementary and secondary school mathematics and science teachers.

The Energy Related Laboratory Equipment (ERLE) activity grants available excess equipment to institutions of higher education for energy-related research.

FY 2004 Accomplishments

- The LSTPD program was implemented at seven national laboratories for 62 teachers. An outside evaluation team was brought in during the planning stages to design the evaluation component of the program.
- The innovative, interactive Internet system developed and implemented for all SC national workforce development programs to receive and process hundreds of student and teacher/faculty applications for summer, fall, and spring semester research appointments at participating DOE laboratories, was modified to include on-line applications for the LSTPD program. The automated system is virtually paperless and provides an excellent example of how the Internet can be used to streamline the operation of DOE's research participation programs. The on-line application system is linked with an SC laboratory central processing center called Education Link. This system enhances communication with the participants regarding their internships; contains pre- and post-surveys that quantify student knowledge, performance and improvement; and allows SC to measure program effectiveness and track students in their academic and career path, and to be a hosting site for publishing student papers, abstracts, and all activity guidelines.
- The Albert Einstein Distinguished Educator Fellowship activity placed four outstanding K-12 science, math, and technology teachers in Congressional offices and two at DOE, as directed by legislation. The National Aeronautics and Space Administration, the NSF, and the National Institute of Standards and Technology contributed funds to place six additional Einstein Fellows in those agencies.
- Five SC laboratories –Argonne, Brookhaven, Lawrence Berkeley, Oak Ridge and Pacific Northwest National Laboratories directly provided support for 31 FaST teams. The NSF has continued as a significant partner in this program and has helped to support these 31 teams. Faculty and students

from colleges and universities with limited prior research capabilities and those institutions serving populations underrepresented in the fields of science, engineering, and technology were part of a research team at a national laboratory. Over a 10 week summer visit to the laboratory, the faculty was 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.

- One faculty member from a participating FaST team partnered with the Lawrence Berkeley National Laboratory in a grant application to the NSF and the partnership was awarded an Advanced Technology Education (ATE) grant.
- The FaST program has laid the foundation for the Faculty Sabbatical program, which will bring faculty from MSIs to national laboratories to enhance their research capabilities as well as the research capacity of their home institution. The Faculty Sabbatical provides support for up to a year of direct research with resident national laboratory scientists on research projects specific to their areas of investigation and courses they teach.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Laboratory Science Teacher Professional Development (LSTPD)..	**1,035**	**1,500**	**1,840**

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-14 students. The national laboratories can play a significant role in providing carefully designed mentor-intensive training for science and math teachers that will allow them to more effectively teach; attract their students' interests to science, mathematics, and technology careers; and improve student achievement. Teachers apply on a competitive basis and are matched with mentors working in their subject fields of instruction. Selected teachers make a 3-year commitment to the LSTPD. Best practice research in teacher professional development indicates that change takes place over an extended period of time and that longer professional development is required. Approximately 62 teachers in FY 2004, 90 teachers in FY 2005 (up to 62 continuing from FY 2004 and the remainder new), and 105 teachers in FY 2006 (up to 90 continuing from FY 2004 and FY 2005, and the remainder new) will spend an intensive four to eight weeks at five or more national laboratories working under the mentorship of master teachers and laboratory mentor scientists to help build content knowledge research skills and a lasting connection with the scientific community through the research experience. Master teachers, who are expert K-14 teachers and adept in both scientific research experience at a national laboratory and scientific writing, will act as liaisons between the mentor scientists and the teacher researchers to help the teachers transfer the research experience to their classroom environments. Follow-on support is considered critical. Master teachers and other teacher participants receive an $800 per week stipend, travel, and housing expenses. All teachers completing the initial immersion experience will be provided monetary support, which consists of approximately $3,000 per year for the three years they are in the program, to purchase materials and scientific equipment, and to help them transfer their research experience to their classroom. Also, follow-on support will include returning to the laboratory in the first year for additional training sessions of approximately one week, and long-term support in following years through communication with other participants and laboratory scientists, more return trips to the national

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

laboratory, and support to present their experience at teaching conferences and publications. Outside evaluation of program effectiveness includes visits to participant teachers' schools and long-term impact of the program on student achievement. Success of this research experience relies on proper placement of each participant to match their professional developmental needs and the follow-on interaction between the teachers and the national laboratories. In FY 2004, this program was initiated at seven national laboratories. The LSTPD supports the DOE's STARS initiative designed to enhance the training of America's mathematics and science teachers; grow students' interest in science and math, especially in the critical middle school years; and draw attention to the women and men who have done DOE science so very well—and thereby encourage young people and prospective teachers to pursue careers in math and science.

Faculty and Student Teams (FaST)	**215**	**265**	**250**

FaST activities at SC Laboratories are being conducted in collaboration with the NSF. Faculty from colleges and universities with limited prior research capabilities and those institutions serving women, minorities, and other populations under represented in the fields of science, engineering, and technology are encouraged to take advantage of the FaST opportunity to prepare students for careers in science, engineering, computer sciences, and technology and for their own professional development. In the first year (FY 2001) of this program, there was one FaST. In part because of increasing support from the NSF, there were six teams in FY 2002, 23 teams in FY 2003, 31 teams in FY 2004, and 33 in FY 2005. In FY 2006, with similar support from NSF, it is projected that there will be about 34 FaST teams. In order to sustain the Faculty Sabbatical Fellowship program, and to add a small number of teachers to the LSTPD fellowship, the FY 2006 DOE contribution is reduced by $15,000 from the FY 2005 level. FaST is a very productive and over-subscribed activity among the laboratory scientists and faculty members and has enjoyed wide support from the national laboratories. It provides an opportunity for faculty to advance their scientific expertise through a close relationship with a national laboratory. Three teams have received peer-reviewed publications that were published in the *Journal of Undergraduate Research*.

Albert Einstein Distinguished Educator Fellowship....	**600**	**700**	**700**

The Albert Einstein Fellowship Awards for outstanding K-12 science, mathematics, and technology teachers continues to be a strong pillar of the program for bringing real classroom and education expertise to our education and outreach activities. Albert Einstein Fellows bring to Congress, DOE, and other Federal agencies the extensive knowledge and experience of classroom teachers. They provide practical insights and "real world" perspectives to policy makers and program managers. The Einstein Fellowship has been a valuable professional growth opportunity for the teachers, as they return to their education field with knowledge of federal resources and an understanding of national education issues. In FY 2006, 13 fellows are supported, the same as FY 2005.

Energy Related Laboratory Equipment (ERLE).........	**80**	**90**	**90**

The ERLE grant activity was established to provide available excess used equipment to institutions of higher education for energy-related research. Through the Energy Asset Disposal System, DOE sites identify laboratory equipment that is then listed on the ERLE website, which is maintained at the Office of Scientific and Technical Information and updated several times a week. Colleges and universities can search for equipment of interest to them and apply via the website. DOE property managers approve or

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006

disapprove the applications. The equipment is free; however, the receiving institution pays all shipping costs.

Faculty Sabbatical Fellowship	**0**	**500**	**200**

The Faculty Sabbatical provides support for up to a year of direct research with resident national laboratory scientists on research projects specific to their areas of investigation and courses they teach. The Faculty Sabbatical activity is designed for each MSI faculty member to work with a national laboratory scientist on a well funded, focused research project of the faculty member's choice. This will not only develop the faculty members' scientific expertise, but also develop their abilities and support their efforts to apply for and receive grants from SC and other granting institutions. Since MSI faculty salaries are comparatively low, their home institutions monetary support is generally insufficient to allow an extended stay at a national laboratory. This sabbatical would match each faculty member's home institution contribution, making their salary more comparable to the level of a national laboratory scientist. This would enable faculty to spend an academic year working on research projects of their interest. It would enhance their research capabilities, adding to their own teaching and research strength, as well as the research capacity of their home institution. Each faculty member can bring their students to the national laboratories, ultimately increasing workforce numbers and diversity. It is the extended stay at the national laboratory, along with the concentrated support from the resident scientists that will enhance them as professors and better prepare them to apply for and receive grants from federal science agencies and other granting institutions. In FY 2005, the initial year of the Faculty Sabbatical Fellowship activity will provide sabbatical research opportunities for 12 faculty members from MSIs to enhance their research capabilities as well as the research capacity of their home institution. Support for this new activity is maintained in FY 2006, but at a reduced level within the overall WDTS program. In FY 2006, there will be five Faculty Sabbatical appointments.

Total, Graduate/Faculty Fellowships	**1,930**	**3,055**	**3,080**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Graduate/Faculty Fellowships	
Laboratory Science Teacher Professional Development	
This increase allows an evaluation of results for the LSTPD activity and supports 15 additional teachers in FY 2006.	+340
Faculty and Student Teams	
The number of SC funded FaST teams participating in a 10-week mentored research experience at a DOE national laboratory is reduced by one (15 in FY 2005 and 14 in FY 2006). However, based upon past support from NSF, it is projected that the program will be able to support 1 additional team in FY 2006.	-15

	FY 2006 vs. FY 2005 ($000)
Faculty Sabbatical Fellowship	
Within the overall reduction in the FY 2006 WDTS program, the Faculty Sabbatical Fellowships are reduced from 12 in FY 2005 to 5 in FY 2006 for faculty members from MSIs.	-300
Total Funding Change, Graduate/Faculty Fellowships	**+25**

Pre-College Activities

Funding Schedule by Activity

(dollars in thousands)

	FY 2004	FY 2005	FY 2006	$ Change	% Change
Pre-College Activities					
National Science Bowl®	725	900	739	-161	-17.9%
Middle School Science Bowl	170	217	250	+33	+15.2%
Total, Pre-College Activities	895	1,117	989	-128	-11.5%

Description

Beyond providing students an opportunity to interact with the scientific community, an additional goal of the middle and high school Science Bowl is to provide opportunities for students interested in science and math to share and demonstrate their talents outside the classroom in an interactive manner that validates their accomplishments and encourages future science and math studies.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA Unit) programs but with additional efforts of the direct (GPRA Unit) programs but with additional efforts from the subprograms which support the GPRA Units in carrying out their mission. Pre-College Activities performs two functions, as indicated in the Supporting Information, in support of the overall SC mission.

Benefits

These Pre-College Activities introduce middle and high school students to the national laboratory system and the available opportunities they may wish to participate in when they go to college.

Supporting Information

The Pre-College Activities subprogram contains two activities which provide an avenue of enrichment, enlightenment, inspiration, and reward through academic science achievement:

The National Science Bowl® is a prestigious educational event that continues to grow in reputation among students, educators, science coaches, and volunteers as a very important educational event and academic tournament. It is a “grass roots” tournament where over 1,800 high schools from all across the nation participate in regional events and where each regional event sends a team to the national event. The regional and national events are primarily volunteer programs where several thousand people dedicate weeks of their time to run and judge educational events and be involved with bright, enthusiastic students who attend science and technology seminars and compete in a verbal forum to solve technical problems and answer questions in all branches of science and math. High school teams also design, build, and race hydrogen fuel cell model cars. Since its inception, more than 90,000 high school students have participated in regional tournaments leading up to the national event. At the national event, students meet numerous DOE and non-DOE scientists and are given a rare chance to learn about the wide variety of careers that scientists in all fields pursue.

The Middle School Science Bowl attracts students at the most critical stage of their academic development. In support of the DOE’s STARS initiative, the Middle School Science Bowl will help create a new generation of scientists who will achieve the scientific breakthroughs and technological advances so essential to our future security and prosperity. The emphasis at this grade level will be on discovery and hands-on activities such as designing, building, and racing model hydrogen fuel cell cars. Students also answer questions in the life and physical sciences and mathematics.

FY 2004 Accomplishments

DOE's National Science Bowl® hosted more than 12,000 high school students in the 64 regional science bowl events.

- The Middle School Science Bowl, initiated in FY 2002 with 8 teams, was expanded to 20 regional sites in FY 2004. The national event in Golden, Colorado, is hosted by the National Renewable Energy Laboratory and the Colorado School of Mines. The event has two main activities: 1) a science and mathematics academic question and answer forum; and 2) a hands-on activity sponsored by General Motors, where each team designs, builds and races a scale-model hydrogen fuel cell car. Teachers are provided a day-long seminar in Hydrogen fuel cells and the Hydrogen economy.
- Saturday morning science seminars were expanded in FY 2004 to include an entire day, at the National Science Bowl® weekend, introducing students to many contemporary issues and findings in contemporary scientific research. These seminars have featured world class scientists and Nobel laureates.
- National Science Bowl® awards were expanded in FY 2004 to include a wide variety of academic awards to the top 18 teams and a Civility Award sponsored by IBM.
- In FY 2004, 16 of the 64 teams took part in designing, building, and racing cars under the Hydrogen Fuel Cell Model Car Challenge that was added to National Science Bowl® in FY 2003. Eight of these teams raced in the stock category and the other eight in the hill climb. Awards were presented to the top teams in this event.

Detailed Justification

(dollars in thousands)

	FY 2004	FY 2005	FY 2006
National Science Bowl®	**725**	**900**	**739**

The National Science Bowl® is one of the few nationally recognized prestigious academic events for high school students. The students answer questions on scientific topics in astronomy, biology, chemistry, mathematics, and physics. In 1991, DOE developed the National Science Bowl® to encourage high school students from across the Nation to excel in mathematics and science and to pursue careers in those fields. The National Science Bowl® provides the students and teachers a forum to receive national recognition for their talent and hard work. The National Science Bowl® includes an entire day of scientific seminars, a set of model car competitions based upon the hydrogen economy of the future and an academic competition. Students participating in the National Science Bowl® will now be tracked to see the long-term impact on their academic and career choices.

The regional and national events are all primarily volunteer programs where several thousand people dedicate a few weeks of their time to organize and judge educational events and be involved with bright, enthusiastic high school students.

	FY 2004	FY 2005	FY 2006
	(dollars in thousands)		
Middle School Science Bowl	**170**	**217**	**250**

It is well recognized that the middle school years are the most productive time to exert an effort to attract students to science and math subjects. There are two events at the Middle School Science Bowl: an academic mathematics and science forum, and an alternative energy model car race. The academic competition is a fast-paced question and answer contest where students answer questions about earth, life, physical, and general sciences and mathematics. The model alternative energy car competition challenges students to design, build, and race model hydrogen fuel cell cars in order to help them understand the future energy challenges that our nation is facing. Students who win in regional events will then enjoy a trip to a national laboratory and participate in a final three-day event that will be designed to capture their interest and reward them for their hard work.

In FY 2006, 24 teams will attend and participate in the National event, the same as the FY 2005 level.

	FY 2004	FY 2005	FY 2006
Total, Pre-College Activities	**895**	**1,117**	**989**

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Pre-College Activities	
National Science Bowl®	
The National Science Bowl® will support 66 teams (a decrease of 2 teams from FY 2005), but will continue to provide a whole day of scientific seminars and workshops for the students. DOE provides all funding for the teams to attend the National finals.	-161
Middle School Science Bowl	
The increased funding will cover the cost for 24 Middle School Science Bowl teams to attend the National finals.	+33
Total Funding Change, Pre-College Activities	**-128**

Safeguards and Security

Funding Profile by Subprogram

(dollars in thousands)

	FY 2004 Comparable Appropriation	FY 2005 Original Appropriation	FY 2005 Adjustments	FY 2005 Comparable Appropriation	FY 2006 Request
Safeguards and Security					
Protective Forces	27,235	28,128	-235[a]	27,893	29,007
Security Systems	5,731	10,656	-57[a]	10,599	11,636
Information Security	2,601	2,983	0	2,983	2,752
Cyber Security	13,283	15,888	-250[a]	15,638	15,840
Personnel Security	5,173	5,900	0	5,900	5,670
Material Control and Accountability	2,116	2,391	0	2,391	2,365
Program Management	6,189	7,369	0	7,369	7,047
Subtotal, Safeguards and Security	62,328	73,315	-542	72,773	74,317
Less Security Charge for Reimbursable Work	-5,598	-5,605	0	-5,605	-5,605
Total, Safeguards and Security	56,730[b]	67,710	-542	67,168	68,712

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

Mission

The mission of the Office of Science (SC) Safeguards and Security program is to ensure appropriate levels of protection against: unauthorized access, theft, diversion, loss of custody or destruction of Department of Energy (DOE) assets and hostile acts that may cause adverse impacts on fundamental science, national security or the health and safety of DOE and contractor employees, the public or the environment.

The SC Program Goals will be accomplished not only through the efforts of the direct (GPRA unit) programs, but with additional efforts from programs which support the GPRA units in carrying out their mission. The Safeguards and Security program performs the following function in support of the overall SC mission: providing protection of employees, facilities and systems in a manner consistent with the security conditions.

Benefits

The benefit of the Safeguards and Security program is that it provides sufficient protection of DOE assets and resources, thereby allowing the programmatic missions of the Department to be conducted in an environment that is secure based on the unique needs of each site. This Integrated Safeguards and Security Management strategy encompasses a graded approach that enables each facility to design its security protection program to meet the facility-specific threat scenario.

[a] Reflects a rescission in accordance with P.L. 108-447, the Consolidated Appropriations Act, 2005.
[b] Includes a reduction of $280,000 rescinded in accordance with the P.L. 108-137, Consolidated Appropriations Act, 2004.

The following is a brief description of the types of activities performed:

Protective Forces

The Protective Forces activity provides for security guards or security police officers and equipment, and training and maintenance needed to effectively carry out the protection tasks during normal and increased or emergency security conditions (SECON). This request is adequate for up to 60 days of heightened security at the SECON 2 level.

Security Systems

The Security Systems activity provides for equipment to protect vital security interests and government property per the local threat. Equipment and hardware include fences, barriers, lighting, sensors, entry control devices, etc.

Information Security

The Information Security activity ensures that materials and documents that may contain classified or “Official Use Only” (OUO) information are accurately and consistently identified; properly reviewed for content; appropriately marked and protected from unauthorized disclosure; and ultimately destroyed in an appropriate manner.

Cyber Security

The Cyber Security activity ensures that OUO information that is electronically processed or transmitted is properly identified and protected, and that all electronic systems have an appropriate level of infrastructure reliability and integrity. This involves perimeter protection, intrusion detection, firewall protection and user authentication. Cyber security also includes enhancements in network traffic logging and monitoring, risk assessments, and improvements in incident response. It provides for the development of virtual private networks and added security for remote login and wireless connections.

Personnel Security

The Personnel Security activity includes security clearance programs, employee security education, and visitor control. Employee education and awareness is accomplished through initial, refresher and termination briefings, computer based training, special workshops, publications, signs, and posters.

Material Control and Accountability

The Material Control and Accountability activity provides for the control and accountability of special nuclear materials, including training of personnel for assessing the amounts of material involved in packaged items, process systems, and wastes. Additionally, this activity provides the programmatic mechanism to ensure that theft, diversion, or operational loss of special nuclear material does not occur. Also included is protection for on- and off-site transport of special nuclear materials.

Program Management

The Program Management activity includes policy oversight and development and updating of security plans, assessments, and approvals to determine if assets are at risk. Also encompassed are contractor management and administration, training, planning, and integration of security activities into facility operations.

Detailed Justification

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Ames Laboratory	**409**	**505**	**505**

The Ames Laboratory Safeguards and Security program coordinates planning, policy, implementation, and oversight in the areas of security systems, protective forces, personnel security, material control and accountability, and cyber security. A protective force is maintained to provide protection of personnel, equipment, and property from acts of theft, vandalism, and sabotage through facility walk-through, monitoring of electronic alarm systems, and emergency communications. Reimbursable work is included in the numbers above; the amount for FY 2006 is $26,000.

Argonne National Laboratory	**7,655**	**8,727**	**8,984**

The Argonne National Laboratory Safeguards and Security program provides protection of nuclear materials, classified matter, government property, and other vital assets from unauthorized access, theft, diversion, sabotage, espionage, and other hostile acts that may cause risks to national security, the health and safety of DOE and contractor employees, the public, or the environment. Other program activities include security systems, material control and accountability, information security, and personnel security. In addition, a protective force is maintained. These activities ensure that the facility, personnel, and assets remain safe from potential threats. The increase in FY 2006 is due to one-time security systems investments to support requirements of the revised Design Basis Threat (DBT). Reimbursable work is included in the numbers above; the amount for FY 2006 is $388,000.

Brookhaven National Laboratory	**10,760**	**11,335**	**11,776**

The Brookhaven National Laboratory (BNL) Safeguards and Security program activities are focused on protective forces, cyber security, physical security, and material control and accountability. BNL operates a transportation division to move accountable nuclear materials around the site. Material control and accountability efforts focus on accurately accounting for and protecting the site's special nuclear materials. The increase in funding for FY 2006 is in protective forces and security systems for reconfiguration and improvements of entry points at the Laboratory. Reimbursable work is included in the numbers above; the amount for FY 2006 is $806,000.

Fermi National Accelerator Laboratory	**2,837**	**3,067**	**3,067**

The Fermi National Accelerator Laboratory Safeguards and Security program efforts are directed at maintaining protective force staffing and operations to protect personnel and the facility, and toward continuing the security systems, and material control and accountability programs to accurately account for and protect the facility's special nuclear materials.

Lawrence Berkeley National Laboratory	**4,689**	**5,785**	**5,205**

The Lawrence Berkeley National Laboratory Safeguards and Security program provides physical protection of personnel and laboratory facilities. This is accomplished with protective forces, security systems, personnel security, and material control and accountability of special nuclear material. The decrease in funding for FY 2006 is primarily because funding is provided in FY 2005 for security system upgrades and improvements of entry points at the laboratory. Reimbursable work is included in the numbers above; the amount for FY 2006 is $830,000.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Oak Ridge Institute for Science and Education	**1,179**	**1,410**	**1,460**

The Oak Ridge Institute for Science and Education (ORISE) Safeguards and Security program provides physical protection/protective force services by employing unarmed security officers. The facilities are designated as property protection areas for the purpose of protecting government-owned assets. In addition to the government-owned facilities and personal property, ORISE possesses small quantities of nuclear materials that must be protected. Reimbursable work is included in the numbers above; the amount for FY 2006 is $319,000.

Oak Ridge National Laboratory	**7,004**	**11,997**	**12,485**

The Oak Ridge National Laboratory (ORNL) Safeguards and Security program includes security systems, information security, cyber security, personnel security, material control and accountability, and program management. Primary security interest is in the National U 233 vault at Building 3019 which requires significant physical security ($3,722,000) and protective force resources that are funded at Oak Ridge Office to meet the DOE DBT. 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. Additionally, ORNL is responsible for providing overall laboratory policy direction and oversight in the security arena. Reimbursable work is included in the numbers above; the amount for FY 2006 is $1,945,000.

Oak Ridge Office	**11,658**	**12,418**	**13,445**

The Oak Ridge Office Safeguards and Security program provides for contractor protective forces for ORNL. This includes protection of a Category I special nuclear material facility, Building 3019 ($8,448,000), the Spallation Neutron Source ($550,000) facility, and the Federal Office Building complex ($3,808,000). Other small activities include security systems, information security, and personnel security ($639,000). The increase in funding for FY 2006 is provided for the revised DBT needs.

Office of Scientific and Technical Information	**60**	**440**	**260**

The Office of Scientific and Technical Information's (OSTI) mission is to collect, preserve, disseminate, and leverage the scientific and technical information resources of DOE to expand the knowledge base of science and technology and facilitate scientific discovery and application. A decrease in FY 2006 is due to one-time costs to support requirements of the revised DBT in FY 2005.

Pacific Northwest National Laboratory	**10,721**	**10,985**	**11,070**

The Pacific Northwest National Laboratory (PNNL) Safeguards and Security program consists of program management, physical security systems, information security, cyber security, personnel security, and material control and accountability. These program elements work together in conjunction with a counterintelligence program and an export control program to ensure appropriate protection and control of laboratory assets while ensuring that PNNL remains appropriately accessible to visitors for technical collaboration. Funding for protective force operations remains the responsibility of the Office of Environmental Management. Reimbursable work is included in the numbers above; the amount for FY 2006 is $1,222,000.

	(dollars in thousands)		
	FY 2004	FY 2005	FY 2006
Princeton Plasma Physics Laboratory	**1,855**	**1,945**	**1,945**

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. Reimbursable work is included in the numbers above; the amount for FY 2006 is $54,000.

Stanford Linear Accelerator Center	**2,214**	**2,341**	**2,511**

The Stanford Linear Accelerator Center Safeguards and Security program focuses on reducing the risk to DOE national facilities and assets. The program consists primarily of protective forces and cyber security program elements. The FY 2006 increase is mainly in security systems for reconfiguration and improvements of entry points at the Laboratory and in cyber security to enhance intrusion detection and system accreditation. Reimbursable work is included in the numbers above; the amount for FY 2006 is $15,000.

Thomas Jefferson National Accelerator Facility	**972**	**1,474**	**1,224**

The Thomas Jefferson National Accelerator Facility has a guard force that provides 24-hour services for the accelerator site and after-hours property protection security for the entire site. Other security programs include cyber security, program management, and security systems. The decrease in funding for FY 2006 is primarily because funding is provided in FY 2005 for security system upgrades and improvements of entry points at the laboratory.

All Other	**315**	**344**	**380**

This funding provides for program management needs for SC and for the Presidential E-Gov initiative of SAFECOM.

Subtotal, Safeguards and Security	**62,328**	**72,773**	**74,317**
Less Security Charge for Reimbursable Work	**-5,598**	**-5,605**	**-5,605**
Total, Safeguards and Security	**56,730**	**67,168**	**68,712**

Detailed Funding Schedule

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
Ames Laboratory					
Protective Forces	143	157	152	-5	-3.2%
Security Systems	38	34	40	+6	+17.6%
Cyber Security	150	227	235	+8	+3.5%
Personnel Security	33	35	33	-2	-5.7%
Material Control and Accountability	5	8	5	-3	-37.5%
Program Management	40	44	40	-4	-9.1%
Total, Ames Laboratory	409	505	505	0	0.0%
Argonne National Laboratory					
Protective Forces	3,202	2,700	2,700	0	0.0%
Security Systems	398	1,098	1,455	+357	+32.5%
Information Security	261	294	294	0	0.0%
Cyber Security	1,666	2,012	2,012	0	0.0%
Personnel Security	1,030	1,067	1,067	0	0.0%
Material Control and Accountability	764	940	940	0	0.0%
Program Management	334	616	516	-100	-16.2%
Total, Argonne National Laboratory	7,655	8,727	8,984	+257	+2.9%
Brookhaven National Laboratory					
Protective Forces	6,412	5,883	6,544	+661	+11.2%
Security Systems	902	889	1,268	+379	+42.6%
Information Security	118	305	133	-172	-56.4%
Cyber Security	2,251	2,729	2,656	-73	-2.7%
Personnel Security	98	490	114	-376	-76.7%
Material Control and Accountability	394	392	392	0	0.0%
Program Management	585	647	669	+22	+3.4%
Total, Brookhaven National Laboratory	10,760	11,335	11,776	+441	+3.9%
Fermi National Accelerator Laboratory					
Protective Forces	1,465	1,656	1,630	-26	-1.6%
Security Systems	461	320	442	+122	+38.1%
Cyber Security	780	910	846	-64	-7.0%
Material Control and Accountability	31	70	36	-34	-48.6%
Program Management	100	111	113	+2	+1.8%
Total, Fermi National Accelerator Laboratory	2,837	3,067	3,067	0	0.0%

(dollars in thousands)	FY 2004	FY 2005	FY 2006	$ Change	% Change
Lawrence Berkeley National Laboratory					
Protective Forces	1,517	1,578	1,578	0	0.0%
Security Systems	815	1,490	790	-700	-47.0%
Cyber Security	1,955	2,259	2,339	+80	+3.5%
Personnel Security	11	9	9	0	0.0%
Material Control and Accountability	16	14	14	0	0.0%
Program Management	375	435	475	+40	+9.2%
Total, Lawrence Berkeley National Laboratory	4,689	5,785	5,205	-580	-10.0%
Oak Ridge Institute for Science and Education					
Protective Forces	282	297	322	+25	+8.4%
Security Systems	106	71	103	+32	+45.1%
Information Security	122	108	108	0	0.0%
Cyber Security	418	541	491	-50	-9.2%
Personnel Security	81	112	118	+6	+5.4%
Program Management	170	281	318	+37	+13.2%
Total, Oak Ridge Institute for Science and Education	1,179	1,410	1,460	+50	+3.5%
Oak Ridge National Laboratory					
Security Systems	1,870	5,055	6,188	+1,133	+22.4%
Information Security	332	411	346	-65	-15.8%
Cyber Security	1,978	2,572	2,657	+85	+3.3%
Personnel Security	1,022	1,095	1,145	+50	+4.6%
Material Control and Accountability	428	458	458	0	0.0%
Program Management	1,374	2,406	1,691	-715	-29.7%
Total, Oak Ridge National Laboratory	7,004	11,997	12,485	+488	+4.1%
Oak Ridge Office					
Protective Forces	11,144	11,964	12,804	+840	+7.0%
Security Systems	134	68	157	+89	+130.9%
Information Security	97	99	105	+6	+6.1%
Personnel Security	283	287	379	+92	+32.1%
Total, Oak Ridge Office	11,658	12,418	13,445	+1,027	+8.3%
Office of Scientific and Technical Information					
Protective Forces	25	25	15	-10	-40.0%
Security Systems	35	215	30	-185	-86.0%
Cyber Security	0	200	190	-10	-5.0%
Program Management	0	0	25	+25	--
Total, Office of Scientific and Technical Information	60	440	260	-180	-40.9%

(dollars in thousands)	FY 2004	FY 2005	FY 2006	$ Change	% Change
Pacific Northwest National Laboratory					
Security Systems	809	886	886	0	0.0%
Information Security	1,671	1,766	1,766	0	0.0%
Cyber Security	2,346	2,319	2,404	+85	+3.7%
Personnel Security	2,615	2,805	2,805	0	0.0%
Material Control and Accountability	478	509	509	0	0.0%
Program Management	2,802	2,700	2,700	0	0.0%
Total, Pacific Northwest National Laboratory	10,721	10,985	11,070	+85	+0.8%
Princeton Plasma Physics Laboratory					
Protective Forces	985	1,260	975	-285	-22.6%
Security Systems	33	33	33	0	0.0%
Cyber Security	545	612	612	0	0.0%
Program Management	292	40	325	+285	+712.5%
Total, Princeton Plasma Physics Laboratory	1,855	1,945	1,945	0	+0.0%
Stanford Linear Accelerator Center					
Protective Forces	1,606	1,829	1,797	-32	-1.7%
Security Systems	0	0	64	+64	--
Cyber Security	601	512	650	+138	+27.0%
Program Management	7	0	0	0	--
Total, Stanford Linear Accelerator Center	2,214	2,341	2,511	+170	+7.3%
Thomas Jefferson National Accelerator Facility					
Protective Forces	454	544	490	-54	-9.9%
Security Systems	130	440	180	-260	-59.1%
Cyber Security	308	453	453	0	0.0%
Material Control and Accountability	0	0	11	+11	--
Program Management	80	37	90	+53	+143.2%
Total, Thomas Jefferson National Accelerator Facility	972	1,474	1,224	-250	-17.0%
All Other					
Cyber Security	285	292	295	+3	+1.0%
Program Management	30	52	85	+33	+63.5%
Total, All Other	315	344	380	+36	+10.5%
Subtotal, Safeguards and Security	62,328	72,773	74,317	+1,544	+2.1%
Less Security Charge for Reimbursable Work	-5,598	-5,605	-5,605	0	0.0%
Total, Safeguards and Security	56,730	67,168	68,712	+1,544	+2.3%

Explanation of Funding Changes

	FY 2006 vs. FY 2005 ($000)
Ames Laboratory	
Minor adjustments within the elements	0
Argonne National Laboratory	
An increase in FY 2006 is primarily due to one-time investments in security systems to support requirements of the revised DBT. The one-time costs include acquisition of surveillance cameras, badge/card readers, and intrusion detection systems, e.g., alarms	+257
Brookhaven National Laboratory	
The increase is primarily associated with security systems-entry points to facilitate more effective and efficient operation to the verification of identification. These entry points will also ease traffic congestion and reduce hazardous conditions during entry. Other adjustments are made to realign funding to FY 2004 level of efforts. One-time adjustments were made in FY 2005 due to findings during a security review.	+441
Fermi National Accelerator Laboratory	
Increase primarily in security systems ($122,000) for operation and maintenance of intrusion detection and alarm systems is offset by adjustments to other elements.	0
Lawrence Berkeley National Laboratory	
A decrease in FY 2006 is primarily because funding is provided in FY 2005 for security system upgrades and improvements of entry points.	-580
Oak Ridge Institute for Science and Education	
Minor adjustments within the elements.	+50
Oak Ridge National Laboratory	
The funding increase is primarily to enhance physical security at the National U 233 vault in Building 3019.	+488
Oak Ridge Office	
The funding increase is primarily to support additional protective force needs at the National U 233 vault in Building 3019 in order to comply with the revised DBT	+1,027
Office of Scientific and Technical Information	
A decrease in FY 2006 is due to one time investments to support requirements of the revised DBT in FY 2005	-180

	FY 2006 vs. FY 2005 ($000)
Pacific Northwest National Laboratory	
The funding increase in FY 2006 is to meet cyber security requirements.	+85
Princeton Plasma Physics Laboratory	
Increase in program management ($285,000) for planning analysis is offset by a decrease in protective force costs resulting from a change in overhead charges against the security funding account	0
Stanford Linear Accelerator Center	
Increases for security systems-entry points to facilitate more effective and efficient operation to the verification of identification, and to ease traffic congestion and reduce hazardous conditions during entry and for cyber security to enhance intrusion detection and system accreditation are offset by a slight decrease in protective forces.	+170
Thomas Jefferson National Accelerator Facility	
A decrease in FY 2006 is primarily because funding is provided in FY 2005 for security system upgrades and improvements of entry points at the laboratory.	-250
All Other	
Minor adjustment for program management needs	+36
Total Funding Change, Safeguards and Security	**+1,544**

Capital Operating Expenses and Construction Summary

Capital Operating Expenses

	(dollars in thousands)				
	FY 2004	FY 2005	FY 2006	$ Change	% Change
General Plant Projects	0	0	470	+470	--
Capital Equipment	102	1,754	2,252	+498	+28.4%
Total, Capital Operating Expenses	102	1,754	2,722	+968	+55.2%